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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY—Bulletin No. 74.

D. E. SALMON, D. V. M., Chief of Bureau.

ENERGY VALUES OF RED CLOVER HAY
AND MAIZE MEAL.

INVESTIGATIONS WITH THE RESPIRATION CALORIMETER,

IN COOPERATION WITH

THE PENNSYLVANIA STATE COLLEGE AGRICULTURAL
EXPERIMENT STATION.

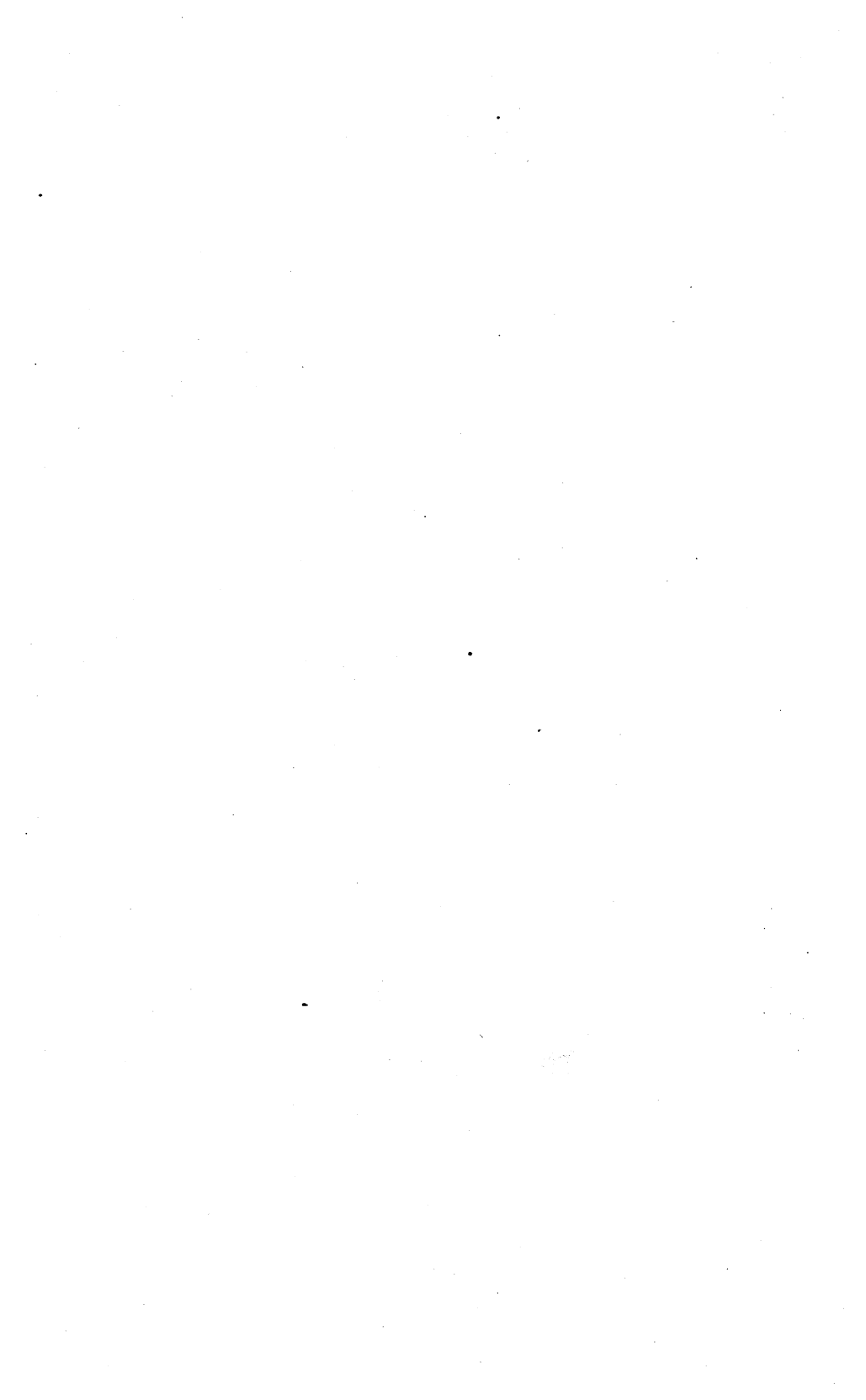
BY

HENRY PRENTISS ARMSBY, Ph. D., LL. D., and J. AUGUST FRIES, B. S.



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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ANIMAL INDUSTRY,
Washington, D. C., June 17, 1905.

SIR: I have the honor to transmit herewith the manuscript of an article dealing with "Energy values of red clover hay and maize meal." This work comprises the results of further careful and difficult experiments carried on, in cooperation with this Bureau, by Dr. H. P. Armsby and J. August Fries at the Pennsylvania Agricultural Experiment Station. I recommend that this manuscript be published as Bulletin No. 74 of the series of this Bureau.

Respectfully,

D. E. SALMON,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

STATE COLLEGE, PA., *April 1, 1905.*

SIR: I have the honor to submit herewith a report upon the second series of cooperative experiments with the respiration calorimeter at the Pennsylvania Experiment Station. The first series, reported in Bulletin No. 51 of the Bureau of Animal Industry, included determinations of the energy values of timothy hay. In the present series the same general methods have been applied to clover hay, and also to maize meal as a representative of the concentrated feeding stuffs. While results upon a single animal must be accepted with some reserve, nevertheless the data obtained indicate certain characteristic differences in the energy values of different classes of feeding stuffs, and appear to show clearly that the more or less current method of comparing feeding stuffs on the basis of their so-called "fuel values" in the body is fundamentally erroneous.

As in the previous experiments, the details of the calorimetric work have been in charge of Mr. Fries, assisted by Messrs. T. M. Carpenter, J. B. Robb, Firman Thompson, and H. L. Wilson. The chemical division of the station, under the general direction of Dr. William Frear, has conducted the necessary chemical work, Mr. M. S. McDowell having had immediate charge of the reception and care of samples. The determinations of carbon and hydrogen were executed by Mr. Thompson and the determinations of heats of combustion by Mr. Carpenter. The weighing and sampling of feeds and excreta and the records of the digestion work were cared for by Mr. A. K. Risser.

Very respectfully,

HENRY PRENTISS ARMSBY,
Expert in Animal Nutrition.

D. E. SALMON, D. V. M.,
Chief of Bureau of Animal Industry.

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ENERGY VALUES OF RED CLOVER HAY AND MAIZE MEAL.

By HENRY PRENTISS ARMSBY, PH. D., LL. D., and J. AUGUST FRIES, B. S.

INTRODUCTORY.

The experiments here reported are a continuation of the investigations described in Bulletin No. 51 of this Bureau, "The available energy of timothy hay." In the experiments there described the metabolism of matter and energy by a steer fed four different amounts of timothy hay together with a small quantity of linseed meal was determined, and the metabolizable, available, and utilizable energy of the hay computed from a comparison of these results. The present experiments, carried out with the same steer in the winter of 1902-3, aimed to determine by similar methods the corresponding energy values for red clover hay and for maize meal.

The general plan of the experiment was as follows: In the first period the animal was given an amount of clover hay estimated to be somewhat less than sufficient for maintenance. In the second period the amount of hay was considerably reduced. A comparison between the first and second periods affords the means of determining the net availability of the energy of the hay. In the third period there was added to the minimum hay ration of the second period an amount of maize meal estimated to be sufficient to make the total ration somewhat less than a maintenance ration. A comparison between Periods II and III affords data for computing the availability of the energy of the maize meal. In the fourth period the maize meal was increased sufficiently to produce a moderate gain, thus affording the means of determining the percentage utilization of the energy of maize meal in the production of gain. It was the intention to add a fifth period, in which the maize meal was to be still further increased, but circumstances prevented. The rations for the several periods were as follows:

Periods and rations.

Period.	Clover hay.	Maize meal.
	<i>Grams.</i>	<i>Grams.</i>
I.....	5,200	0
II.....	3,700	0
III.....	3,700	850
IV.....	3,700	4,000

The animal used was the same grade Shorthorn steer which served in the experiments of 1901-2. At the time of these experiments he was approximately four years old.

DESCRIPTION OF THE EXPERIMENTS.

ANALYTICAL METHODS.

The methods employed for the analysis of the feed and excreta were substantially those recommended by the Association of Official Agricultural Chemists. The nitrogen of the feces was determined in the fresh material by König's method and the nitrogen of the urine by direct oxidation by the Kjeldahl method. In the computation of proteids from proteid nitrogen, the factor 6.0 was used for the maize meal and the conventional factor 6.25 for the clover hay. The non-proteids were computed from the nonproteid nitrogen by multiplication by 4.7, the factor for asparagin. Carbon and hydrogen were determined by combustion with cupric oxide in a current of air, followed by oxygen. The heats of combustion of the food and excreta were determined by means of the Atwater-Hempel bomb calorimeter.

THE FEEDS.

Hay.—The hay used was second-growth red clover hay grown on the station farm in the summer of 1902. It was cut on August 16 and hauled to the barn August 20 to 22. It was secured without rain and retained most of the leaves on the stems. On December 4 about a ton of this hay was run through a Ross feed cutter and cut to lengths of about 7 to 10 centimeters. From the mass of cut hay two separate samples were taken by the same method as in the previous experiment.^a During the progress of the experiments a sample of hay was also taken at time of weighing out for each period, as described in subsequent pages, or four samples in all. The following table shows the composition of the dry matter of the several samples, the generally close agreement of the results indicating that the method was sufficiently accurate:

Composition of clover hay (dry matter).

Constituents and energy.	General samples.			Samples taken during experiments.			
	A.	B.	Average.	Period I.	Period II.	Period III.	Period IV.
Ash .....per cent..	6.26	6.53	6.40	6.40	6.46	6.64	6.64
Proteids (N.×6.25).....do....	12.83	12.96	12.90	11.77	12.06	13.11	12.82
Nonproteids .....do....	1.52	1.69	1.61	1.81	1.60	1.87	1.14
Crude fiber.....do....	31.48	31.74	31.61	33.87	33.67	31.48	32.63
Nitrogen-free extract...do....	45.25	44.40	44.81	43.25	43.51	44.05	43.90
Ether extract .....do....	2.66	2.68	2.67	2.90	2.70	2.85	2.87
	100.00	100.00	100.00	100.00	100.00	100.00	100.00

^a Compare Bureau of Animal Industry Bulletin No. 51, p. 10.

Composition of clover hay (dry matter)—Continued.

Constituents and energy.	General samples.			Samples taken during experiments.			
	A.	B.	Average.	Period I.	Period II.	Period III.	Period IV.
Total nitrogen .....per cent..	2.376	2.439	2.408	2.265	2.271	2.494	2.292
Albuminoid nitrogen ...do....	2.053	2.079	2.066	1.882	1.930	2.098	2.050
Carbon.....do....	45.60	45.31	45.44	45.25	45.93	45.40	45.60
Hydrogen.....do....	6.45	6.19	6.34	6.11	6.27	5.90	6.01
Energy....Calories per gram..	4,469.0	4,445.8	4,457.4	4,449.4	4,426.5	4,421.0	4,449.4

Maize meal.—The maize meal used was purchased from a firm of feed dealers in Bellefonte, Pa., and was stated to be from old yellow corn. It was of excellent quality. Two separate samples were taken of this meal on very nearly the same plan as in the case of the hay. The meal was then stored in a galvanized-iron tank with a wooden cover. At the time of weighing out for the third and fourth periods, samples were also taken for analysis. The following table shows the composition of the dry matter of these several samples:

Composition of maize meal (dry matter).

Constituents and energy.	General Samples.			Samples taken during experiments.	
	A.	B.	Average.	Period III.	Period IV.
Ash .....per cent..	1.41	1.33	1.37	1.48	1.45
Proteids (N.×6.00) .....do....	10.35	9.53	9.94	9.46	10.20
Nonproteids (N.×4.7).....do....	.17	.78	.48	.68	.29
Crude fiber.....do....	2.72	2.48	2.60	2.38	2.19
Nitrogen-free extract.....do....	81.16	81.61	81.38	81.90	81.65
Ether extract.....do....	4.19	4.27	4.23	4.10	4.22
	100.00	100.00	100.00	100.00	100.00
Total nitrogen .....do....	1.762	1.753	1.758	1.721	1.761
Proteid nitrogen .....do....	1.726	1.588	1.657	1.575	1.700
Carbon.....do....	44.88	45.17	45.03	45.59	45.75
Hydrogen.....do....	6.59	6.70	6.65	6.83	6.91
Energy.....Calories per gram..	4,458.9	4,403.2	4,431.1	4,359.8	4,365.9

PERIODS AND RATIONS.

On November 12, 1902, the steer was put on a ration of 12 pounds of uncut clover hay of the same kind as that prepared for the experiment. The weekly weighings of the animal indicated that this amount of hay was approximately a maintenance ration. On January 23, 1903, the animal was removed from the barn to the calorimeter building and put upon the ration of the first period. The hay was somewhat dusty as a result of the considerable handling which it had received, and it was sprinkled with a small amount of water to facilitate its consumption, 520 grams of water being used daily. The hay was fed in approximately equal feeds night and morning.

Each period covered twenty-one days, of which the first eleven were regarded as a preliminary period, and the last ten as constituting the digestion period proper. The table shows the exact dates of the several periods, the rations being also repeated as a matter of convenience:

Dates and rations.

Period.	Date.		Ration.	
	Preliminary period.	Digestion period.	Clover.	Maize meal.
	1903.	1903.	Grams.	Grams.
I	Jan. 24-Feb. 3	Feb. 4-13	5,200 .....	.....
II	Feb. 14-24	Feb. 25-Mar. 6	3,700 .....	.....
III	Mar. 7-17	Mar. 18-27	3,700	850
IV	Mar. 28-Apr. 7	Apr. 8-17	3,700	4,000

The animal was watered daily at about 1 p. m., except the days when he was in the calorimeter and the day before and after, when water was given immediately after the morning feeding.

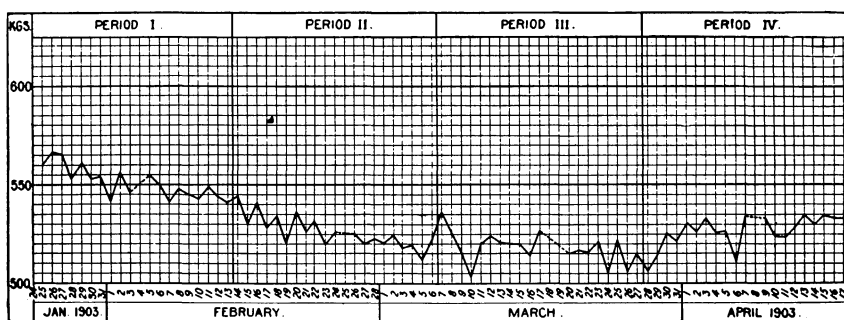


DIAGRAM I.—Live weights.

LIVE WEIGHTS.

The animal was weighed daily at 1 p. m., immediately before watering and also immediately after, the difference being taken as representing the amount of water consumed. On the days when the animal was in the calorimeter the weight was taken immediately before entering and immediately after leaving the apparatus. The figures for live weight and amount of water consumed are given in Table I of the Appendix in connection with the weights of the excreta, and the live weights are shown graphically on Diagram I above:

DETERMINATIONS OF DIGESTIBILITY.

WEIGHING AND SAMPLING OF THE FEED.

Hay.—The hay for each period was weighed out in advance in cloth bags, a day's ration in a bag. In filling the bags the mass of hay was worked into from the side, taking all the material down to the floor. While the bags were being filled two or three large handfuls of the hay

were taken from each bag and set aside in a covered vessel. Immediately after the weighing this sample was rapidly chopped in a meat chopper, thoroughly mixed, and a sample of 1,000 to 1,500 grams taken immediately to the laboratory in a covered vessel for determination of dry matter and of the composition of the latter, with the results shown in the table on pages 8 and 9.

Maize meal.—The maize meal required was also weighed out in advance for each period in tightly covered tin pails, which were kept in a cool place until used. At the time of weighing, a sample of 300 to 400 grams was drawn and taken immediately to the laboratory for determination of dry matter and its several ingredients, with the results shown on page 9.

TREATMENT OF SAMPLES.

The samples when received at the laboratory were immediately weighed, air dried at a temperature of about 60° C., allowed to hang at ordinary temperature in heavy paper bags for several days, and then ground in a mill as rapidly as practicable, and preserved in sealed bottles. The analyses were made as promptly as practicable, although not in all cases immediately.

HOURS OF FEEDING.

As a matter of convenience in arranging for the work with the respiration calorimeter, the hour of 6 p. m. was taken as the beginning of the day. Approximately one-half of the hay and maize meal was given at this time and the remainder twelve hours later.

COLLECTION AND SAMPLING OF THE EXCRETA.

The animal was provided with the rubber duct described and illustrated in a previous publication,^a for the collection of the feces, and with the ordinary urine funnel. During the experiments these were worn constantly, both during the preliminary days and during the digestion period proper. The apparatus served its purpose excellently, loss of excreta occurring in few instances.

During the digestion period the excreta were weighed promptly at the end of each twenty-four hours, a sample drawn, after thorough mixing, and taken at once to the laboratory for treatment. There a uniform percentage of the total excretion was set aside for a composite sample, chloroform being employed as a preservative. At the close of the period these composite samples were thoroughly mixed. In the feces the total nitrogen in the fresh substance was determined by the König method, while a portion of the composite sample was also air dried at 60° C. and the air-dry sample subjected to the usual method of analysis, including the determination of its heat of combustion and of carbon and hydrogen. In the mixed sample of urine the total nitrogen, total carbon, hydrogen in organic combination, and heat of combustion were determined.

^a Penn. Experiment Station Bulletin No. 42, p. 74.

Feed and excreta.

Feed and excreta.	Fresh weight.	Dry matter.	
	Grams.	Per cent.	Grams.
Hay:			
Total in 10 days	37,000.0	84.97	31,438.9
Eaten per day	3,700.0	.....	3,143.9
Feces:			
Collected in 10 days	56,602.0	22.36	12,656.2
Spilled in calorimeter	19.4	69.88	13.6
Total excretion	56,621.4	.....	12,669.8
Daily excretion	5,662.1	.....	1,267.0

Digestibility of ration.

		Total digested.	Digestibility.
			Per cent.
Dry matter	grams.	1,876.9	59.70
Ash	do.	94.4	46.48
Organic matter	do.	1,782.5	60.61
Proteids	do.	201.7	53.19
Nonproteids ^a	do.	50.3	(100.00)
Crude fiber	do.	532.1	50.27
Nitrogen-free extract	do.	943.0	68.94
Ether extract	do.	55.2	65.02
Nitrogen	do.	43.0	60.23
Carbon	do.	826.9	57.27
Energy	Calories.	8,078.8	58.05

^a Assumed to be entirely digestible.*Period III (March 7 to 27, 1903).*

In this period the final results were as follows:

Feed and excreta.

Feed and excreta.	Fresh weight.	Dry matter.	
	Grams.	Per cent.	Grams.
Hay:			
Total in 10 days	37,000.0	85.48	31,627.6
Eaten per day	3,700.0	.....	3,162.8
Maize meal:			
Total in 10 days	8,500.0	86.44	7,347.4
Eaten per day	850.0	.....	734.7
Feces:			
Total collected	68,006.0	20.04	13,628.4
Spilled in calorimeter	29.0	49.90	14.5
Spilled in stall February 20	45.9	23.14	10.6
Spilled in stall February 22	78.2	20.70	16.2
Spilled in stall February 24	8.4	25.71	2.2
Spilled in stall February 26	10.6	33.90	3.6
Total excretion	68,178.1	.....	13,675.5
Daily excretion	6,817.8	.....	1,367.6

Digestibility of ration.

Constituents and energy.	Total digested.	Digestibility.
		<i>Per cent.</i>
Dry matter grams..	2,529.9	64.91
Ash.....do....	94.8	42.91
Organic matter.....do....	2,435.1	66.26
Proteids.....do....	276.2	57.05
Nonproteids ^a.....do....	64.1	(100.00)
Crude fiber.....do....	453.8	44.79
Nitrogen-free extract.....do....	1,551.0	77.75
Ether extract.....do....	89.8	74.71
Nitrogen.....do....	58.2	63.68
Carbon.....do....	1,109.4	62.66
Energy.....Calories..	10,854.4	63.16

^a Assumed to be entirely digestible.*Period IV (March 28 to April 7, 1903).*

Tabulated as before, the results for this period are:

Feed and excreta.

Feed and excreta.	Fresh weight.	Dry matter.	
	<i>Grams.</i>	<i>Per cent.</i>	<i>Grams.</i>
Hay:			
Total in 10 days	37,000.0	86.12	31,864.0
Eaten per day	3,700.0		3,186.4
Maize meal:			
Total in 10 days	40,000.0	86.27	34,508.0
Eaten per day	4,000.0		3,450.8
Feces:			
Total collected	86,763.0	18.09	15,695.4
Stall correction.....	388.6	20.37	78.1
Total excretion.....	87,146.6		15,773.5
Daily excretion.....	8,714.7		1,577.4

Digestibility of ration.

Constituents and energy.	Total digested.	Digestibility.
		<i>Per cent.</i>
Dry matter grams..	5,059.8	76.23
Ash.....do....	107.5	41.09
Organic matter.....do....	4,952.3	77.68
Proteids.....do....	441.2	58.01
Nonproteids ^a.....do....	46.3	(100.00)
Crude fiber.....do....	547.1	49.05
Nitrogen-free extract.....do....	3,718.7	88.20
Ether extract.....do....	198.8	83.89
Nitrogen.....do....	81.9	61.58
Carbon.....do....	2,271.1	74.92
Energy.....Calories..	21,912.6	74.93

^a Assumed to be entirely digestible.

THE URINARY EXCRETION.

Table IV of the Appendix, based upon the weights recorded in Table I, shows the total amounts of nitrogen, carbon, and potential energy in the urine. In those cases in which some was spilled, the material was taken up as completely as possible with the aid of distilled water and the weight and nitrogen content of the washings determined. It has been assumed that their content of carbon and of energy was proportional to the nitrogen. The following table gives a summary of the average daily excretion:

Average daily excretion in urine.

Period.	Nitrogen.	Carbon.	Energy.	Energy per gram of carbon.
	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>	<i>Calories.</i>
I	74.97	150.46	1,249.8	8.31
II	58.50	103.43	933.5	9.05
III	59.01	125.31	920.9	7.35
IV	70.23	141.87	1,194.3	8.42

It will be observed from the above table that the energy per gram of carbon was considerably less than that found by Kellner in similar experiments and likewise lower than the results found by ourselves in the previous year's experiments. We believe this discrepancy is due to the fact that the urine samples were dried at too high a temperature. The loss of nitrogen in drying was determined and a correction made for it on the assumption that this loss represented urea decomposed during the drying. Determinations of the loss of carbon, however, gave much higher figures than corresponded to the loss of nitrogen on the above assumption, making it evident that some material other than urea was being decomposed. Under these circumstances it has been thought best to discard the above results for energy and to compute the energy contained in the urine on the basis of Kellner's average figures.

GROWTH OF EPIDERMAL TISSUE.

The steer was thoroughly brushed immediately before entering the calorimeter and after leaving it, and the hair, dandruff, etc., in the latter case collected. To this was added the small amount brushed up from the floor of the calorimeter. In these samples determinations of nitrogen, carbon, and energy were made with the following results:

Weights and composition of brushings.

Constituents and energy.	Period I.	Period II.	Period III.	Period IV.
Weight .....grams..	23.0	24.3	47.5	57.4
Dry matter .....per cent..	94.45	93.29	90.15	90.01
Weight of dry matter.....grams..	21.72	22.67	42.82	51.67
In dry matter:				
Nitrogen—				
Percentage	6.59	7.41	8.69	7.91
Weight .....grams..	1.43	1.68	3.72	4.09
Carbon—				
Percentage	42.73	39.97	43.88	42.78
Weight .....grams..	9.28	9.06	18.79	22.10
Energy—				
Per gram .....Calories..	4.529	4.442	4.815	4.660
Total .....do....	98.36	100.67	206.2	240.8

On the average of the four periods the amounts of nitrogen, carbon, and energy contained in the brushings were as follows:

Average composition of brushings.

Constituents and energy.	Total.	Per day.
Nitrogen.....grams..	3.73	1.87
Carbon .....do....	14.81	7.40
Energy .....Calories..	161.5	80.8

In the computations on the following pages it has been assumed that these figures represent the normal rate of production of hair, epidermis, etc., by the animal during the experiment. They do not, of course, include the matter and energy contained in the growth of hoofs and horns:

DETERMINATIONS OF RESPIRATORY PRODUCTS.

Upon the first two days of the digestion period proper in each period the respiratory products were determined during forty-eight hours continuously, the time being divided into four subperiods of twelve hours each. The apparatus used was the respiration calorimeter briefly described in Bulletin No. 51, Bureau of Animal Industry, and more fully in a subsequent publication.^a

It is impracticable to reproduce here all the details of these determinations. For the general methods employed the reader is referred to the previous bulletin.

^a Experiment Station Record, Vol. XV, p. 1037.

CHECK TESTS.

External air.—As noted in Bulletin No. 51, check tests are depended upon as a means of computing the amount of combustible gases contained in the air as it enters the respiration chamber. The check tests were made at intervals during the experiments here described with the following results:

Combustible gases in air.

Date.	Volume of air.	Water weighed.	Carbon dioxide weighed.	Per 100 liters air at 0° C. and 760 mm.	
				Hydrogen.	Carbon.
	Liters.	Gram.	Gram.	Milligram.	Milligram.
January 27, 1903	1,200	0.01752	0.00683	0.178	0.170
February 16, 1903	1,250	.02991	.00331	.301	.082
March 3, 1903	1,200	.02259	.00863	.229	.215
March 23, 1903	1,100	.02269	.00644	.255	.178
April 30, 1903	1,250	.02479	.00803	.247	.196
Average				.242	.168

As in the previous year the results are somewhat variable, but in no case are the corrections large as compared with the total amounts determined in the experiments upon the animal.

Alcohol check tests.—The accuracy of the apparatus was tested as in the previous year by burning in it known amounts of ethyl alcohol and determining the amounts of carbon dioxide, water, and heat evolved. The results of these alcohol check tests as regards carbon dioxide and heat are given below. The results upon water have not yet proven satisfactory.

Results of alcohol check tests.

Date.	No. of hours.	Weight of alcohol.		Carbon dioxide.			Heat.		
		Hydrated.	Anhydrous.	Computed.	Observed.	Percentage observed.	Computed.	Observed.	Percentage observed.
		Grams.	Grams.	Grams.	Grams.		Calories.	Calories.	
Jan. 20, 1903..	6	527.67	475.62	908.91	891.58	98.1	3,417.09	3,427.16	100.3
Mar. 26, 1903 .	6	526.53	474.60	906.96	891.24	98.3	3,409.76	3,407.01	99.9
Apr. 28, 1903..	6	503.16	453.53	866.69	855.73	98.7	3,258.38	3,190.31	97.9

RESULTS UPON THE ANIMAL.

Tables V, VI, VII, VIII, IX, and X of the Appendix contain the results of the respiratory determinations for the several periods and subperiods. These are summarized in the table following.

Carbon and hydrogen excretion.

Period.	In CO ₂ and H ₂ O.		In hydrocarbons.	
	Carbon.	Hydrogen.	Carbon.	Hydrogen.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Period I:				
Subperiod 1	590.8	262.9	39.38	12.52
Subperiod 2	592.6	262.9	39.25	12.36
First day	1,183.4	525.8	78.63	24.88
Subperiod 3	603.4	244.0	38.84	12.40
Subperiod 4	586.0	253.5	36.90	11.64
Second day	1,189.4	497.5	75.74	24.04
Average	1,186.4	511.7	77.19	24.46
Period II:				
Subperiod 1	499.7	218.9	28.34	8.66
Subperiod 2	508.4	253.8	27.22	8.47
First day	1,008.1	472.7	55.56	17.13
Subperiod 3	506.4	251.3	29.29	8.69
Subperiod 4	493.3	255.4	29.50	8.83
Second day	999.7	506.7	58.79	17.52
Average	1,003.9	489.7	57.18	17.33
Period III:				
Subperiod 1	539.8	248.9	38.47	12.51
Subperiod 2	543.5	282.4	38.09	12.16
First day	1,083.3	531.3	76.56	24.67
Subperiod 3	577.7	267.6	40.06	12.72
Subperiod 4	546.7	271.9	38.66	12.23
Second day	1,124.4	539.5	78.72	24.95
Average	1,103.9	535.4	77.64	24.81
Period IV:				
Subperiod 1	830.5	415.5	64.32	20.92
Subperiod 2	852.4	447.5	71.36	23.16
First day	1,682.9	863.0	135.68	44.08
Subperiod 3	821.3	442.6	67.43	21.80
Subperiod 4	843.6	461.3	70.70	23.00
Second day	1,664.9	903.9	138.13	44.80
Average	1,673.9	883.5	136.91	44.44

Hydrocarbon gases.—In the experiment with timothy hay in 1901–02 it was shown that the ratio of hydrogen to carbon in the combustible gases given off by the animal was almost identical with that for methane. The corresponding results for the present experiment were as follows:

Ratio of hydrogen to carbon in combustible gases.

Period I:	
Subperiod 1	1:3.145
Subperiod 2	1:3.176
First day	1:3.160

Period I—Continued.

Subperiod 3	1:3.132
Subperiod 4	1:3.170
Second day	1:3.155

Average, Period I 1:3.156

Period II:

Subperiod 1	1:3.273
Subperiod 2	1:3.214
First day	1:3.244
Subperiod 3	1:3.371
Subperiod 4	1:3.341
Second day	1:3.356

Average, Period II 1:3.299

Period III:

Subperiod 1	1:3.075
Subperiod 2	1:3.133
First day	1:3.103
Subperiod 3	1:3.150
Subperiod 4	1:3.163
Second day	1:3.155

Average, Period III 1:3.129

Period IV:

Subperiod 1	1:3.074
Subperiod 2	1:3.081
First day	1:3.078
Subperiod 3	1:3.093
Subperiod 4	1:3.074
Second day	1:3.083

Average, Period IV 1:3.078

Computed for CH_4 1:2.976

According to the above figures, the ratio of hydrogen to carbon is somewhat less than that required for methane. The computed percentage composition of the combustible gases compared with that computed for CH_4 was as follows:

Percentage composition of combustible gases.

Gas.	Observed; average.	Observed; excluding Period II.	Computed for CH_4 .
Carbon	76.00	75.74	74.85
Hydrogen	24.00	24.26	25.15
	100.00	100.00	100.00

The agreement with the composition of methane is less satisfactory than in the previous series of experiments, yet it seems difficult to account for a deficiency of hydrogen.

If we assume that the combustible gases consist of methane and compute its amount from the amounts of carbon found, we have the following as the excretion of methane in the several periods:

Period I:	Grams.	Period III:	Grams.
Subperiod 1.....	52.62	Subperiod 1.....	51.40
Subperiod 2.....	52.44	Subperiod 2.....	50.89
Subperiod 3.....	51.89	Subperiod 3.....	53.52
Subperiod 4.....	49.30	Subperiod 4.....	51.65
Average per day.....	103.13	Average per day.....	103.73
Period II:		Period IV:	
Subperiod 1.....	37.86	Subperiod 1.....	85.93
Subperiod 2.....	36.37	Subperiod 2.....	95.34
Subperiod 3.....	39.13	Subperiod 3.....	90.08
Subperiod 4.....	39.41	Subperiod 4.....	94.46
Average per day.....	76.39	Average per day.....	182.91

DETERMINATIONS OF HEAT.

It is impracticable to reproduce here the very voluminous records required for the determination of the heat produced, and it must suffice to indicate the general method and to summarize the main results.

As explained in Bureau of Animal Industry Bulletin No. 51, the heat given off by the animal as sensible heat is removed from the apparatus by a water current, the amount thus removed being measured by the product of the amount of water passing through the absorbers and the rise in temperature during its passage through the apparatus. As noted, the temperature of the water was taken every four minutes, while the efflux of each 100 liters was noted on the records. In any portion of the experiment during which the rate of flow of water is uniform we may, without sensible error, compute the averages of the ingoing and of the outcoming temperatures and multiply the total weight of water by the difference between the two. Certain corrections are necessary, however.

First. The pipe composing our absorber being of small diameter, there is a not inconsiderable pressure upon the bulbs of the thermometers, and this pressure varies with the rate at which the water flows. Since the pressure is greater upon the ingoing than upon the outcoming thermometer, the effect is to render the observed difference in temperature too small. A correction for this effect was worked out experimentally for the range of pressure used, and is applied in the table.

Second. The friction of the water in the absorbers is itself a source of a small amount of heat, which has been computed from the differ-

ence in pressure at entrance and exit and the weight of the water passing through the absorbers.

Third. As Atwater and Rosa have shown, it is essential to take account of the variation in the specific heat of water at different temperatures. We have followed their practice, and assuming the specific heat of water at 20° C. as unity, have expressed all our results in Calories at 20°, using for this purpose the table of the specific heat of water given by those observers.^a

Fourth. Corrections have to be made for the heat introduced into the apparatus or withdrawn from it in case the feed, drink, excreta, and vessels containing them were introduced or removed at a temperature different from that of the calorimeter. The net amount of these corrections, as appears from the table, is ordinarily small, but the single factors are sometimes not inconsiderable. This is especially the case with the feces, where considerable difficulty was experienced in determining the true average temperature of the mass.

The results of these several computations are contained in Table XI of the Appendix. To the heat thus measured is to be added the latent heat of water vapor produced in and carried out of the chamber. This is computed from the results for water, assuming the latent heat of vaporization to be 0.592 Calorie per gram.

The following table contains a summary of the amounts of heat measured in the calorimeter in the several periods and subperiods:

Heat measured in calorimeter.

Subperiod.	Heat measured.			
	Period I.	Period II.	Period III.	Period IV.
First day:	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
Subperiod 1	5,805.27	5,444.53	5,318.83	7,306.18
Subperiod 2	5,878.48	4,813.02	4,971.53	7,424.14
Total	11,683.75	10,257.55	10,290.36	14,730.32
Second day:				
Subperiod 1	6,010.82	4,971.32	5,716.51	7,085.07
Subperiod 2	5,616.18	4,944.16	5,053.88	7,418.97
Total	11,627.00	9,915.48	10,770.39	14,504.04
Average per day	11,655.38	10,086.52	10,530.38	14,617.18

RATE OF HEAT EMISSION.

As in the previous experiment, the rate at which heat was given off by the animal varied remarkably according as the animal was standing or lying. The readings of the thermometers, which were taken every four minutes, furnish an approximately continuous measurement of the rate at which heat was given off by the animal by

^aU. S. Department of Agriculture, Office of Experiment Stations Bull. No. 63, p. 56.

radiation and conduction. The individual readings are probably subject to some accidental fluctuations. To eliminate these, each three successive readings have been averaged and multiplied by the amount of water passing through the absorbers during the same twelve minutes. The results, expressed in Calories per minute, are represented graphically on Diagram II, in which the arrows indicate the times at which the animal stood up or lay down, the possible effects of slight variations in the temperature of the calorimeter itself being disregarded.

The following table shows the total heat emitted during the periods of standing and lying, respectively. The figures of this table relate only to the amount of heat given off by radiation and conduction and removed from the calorimeter in the water current and do not include the heat carried off as latent heat of water vapor.

Heat emission.

Period and subperiod.	Time.	Position.	Total heat.	Heat per minute.
Period I:				
Subperiod 1—	<i>Minutes.</i>		<i>Calories.</i>	<i>Calories.</i>
6.00 p. m. to 7.46 p. m.	106	Standing	786.05	6.9439
7.46 p. m. to 10.30 p. m.	164	Lying	857.20	5.2268
10.30 p. m. to 1.02 a. m.	152	Standing	1,122.61	7.3856
1.02 a. m. to 2.03 a. m.	61	Lying	275.43	4.5152
2.03 a. m. to 4.20 a. m.	137	Standing	976.18	7.1254
4.20 a. m. to 6.00 a. m.	100	Lying	442.62	4.4262
Subperiod 2—				
6.00 a. m. to 6.30 a. m.	30	do	138.31	4.6103
6.30 a. m. to 9.08 a. m.	158	Standing	1,158.72	7.3337
9.08 a. m. to 11.22 a. m.	134	Lying	606.08	4.5230
11.22 a. m. to 3.48 p. m.	266	Standing	1,864.81	7.1006
3.48 p. m. to 5.34 p. m.	106	Lying	460.09	4.3405
5.34 p. m. to 6.00 p. m.	26	Standing	206.97	7.9604
Subperiod 3—				
6.00 p. m. to 8.10 p. m.	130	do	981.05	7.5462
8.10 p. m. to 10.06 p. m.	116	Lying	588.37	5.0722
10.06 p. m. to 4.28 a. m.	382	Standing	2,735.70	7.1615
4.28 a. m. to 6.00 a. m.	92	Lying	403.63	4.3873
Subperiod 4—				
6.00 a. m. to 6.38 a. m.	38	do	171.78	4.5205
6.38 a. m. to 10.18 a. m.	220	Standing	1,482.86	6.7403
10.18 a. m. to 12.50 p. m.	152	Lying	650.75	4.2813
12.50 p. m. to 3.10 p. m.	140	Standing	999.08	7.1363
3.10 p. m. to 5.10 p. m.	120	Lying	533.37	4.4448
5.10 p. m. to 6.00 p. m.	50	Standing	388.18	7.7636
Period II:				
Subperiod 1—				
6.00 p. m. to 10.10 p. m.	250	do	1,461.47	5.8459
10.10 p. m. to 12.20 a. m.	130	Lying	512.35	3.9412
12.20 a. m. to 6.00 a. m.	340	Standing	2,305.81	6.7818
Subperiod 2—				
6.00 a. m. to 10.42 a. m.	282	do	1,390.84	4.9321
10.42 a. m. to 1.20 p. m.	158	Lying	595.17	3.7669
1.20 p. m. to 6.00 p. m.	280	Standing	1,462.70	5.2239



Heat emission—Continued.

Period and subperiod.	Time.	Position.	Total heat.	Heat per minute.
Period II—Continued.				
Subperiod 3—	<i>Minutes.</i>		<i>Calories.</i>	<i>Calories.</i>
6.00 p. m. to 9.00 p. m.	180	Standing	1,031.79	5.7322
9.00 p. m. to 11.58 p. m.	178	Lying	683.85	3.8419
11.58 p. m. to 1.54 a. m.	116	Standing	748.60	6.4534
1.54 a. m. to 3.50 a. m.	116	Lying	482.81	4.1622
3.50 a. m. to 4.48 a. m.	58	Standing	412.31	7.1088
4.48 a. m. to 6.00 a. m.	72	Lying	274.82	3.8169
Subperiod 4—				
6.00 a. m. to 8.48 a. m.	168	do	721.40	4.2940
8.48 a. m. to 11.12 a. m.	144	Standing	879.28	6.1061
11.12 a. m. to 3.16 p. m.	244	Lying	978.50	4.0102
3.16 p. m. to 6.00 p. m.	164	Standing	975.46	5.9479
Period III:				
Subperiod 1—				
6.00 p. m. to 7.45 p. m.	105	do	607.27	5.7835
7.45 p. m. to 11.15 p. m.	210	Lying	946.64	4.5078
11.15 p. m. to 1.04 a. m.	109	Standing	803.49	7.3715
1.04 a. m. to 3.19 a. m.	135	Lying	605.89	4.4881
3.19 a. m. to 6.00 a. m.	161	Standing	1,048.14	6.5049
Subperiod 2—				
6.00 a. m. to 7.50 a. m.	110	 do	647.80	5.8891
7.50 a. m. to 11.47 a. m.	237	Lying	789.48	3.3311
11.47 a. m. to 12.44 p. m.	57	Standing	402.71	7.0651
12.44 p. m. to 3.44 p. m.	180	Lying	787.62	4.3757
3.44 p. m. to 6.00 p. m.	136	Standing	858.28	6.3109
Subperiod 3—				
6.00 p. m. to 6.52 p. m.	52	do	334.89	6.4402
6.52 p. m. to 7.34 p. m.	42	Lying	179.81	4.2812
7.34 p. m. to 9.23 p. m.	109	Standing	800.92	7.3479
9.23 p. m. to 9.31 p. m.	8	Lying	19.19	2.3988
9.31 p. m. to 11.11 p. m.	100	Standing	722.82	7.2282
11.11 p. m. to 12.11 a. m.	60	Lying	244.36	4.0727
12.11 a. m. to 2.33 a. m.	142	Standing	997.05	7.0215
2.33 a. m. to 3.18 a. m.	45	Lying	179.47	3.9882
3.18 a. m. to 6.00 a. m.	162	Standing	988.65	6.1028
Subperiod 4—				
6.00 a. m. to 8.40 a. m.	160	do	813.84	5.0865
8.40 a. m. to 11.17 a. m.	157	Lying	550.95	3.5092
11.17 a. m. to 2.14 p. m.	177	Standing	1,058.35	5.9794
2.14 p. m. to 5.18 p. m.	184	Lying	731.27	3.9743
5.18 p. m. to 6.00 p. m.	42	Standing	256.49	6.1069
Period IV:				
Subperiod 1—				
6.00 p. m. to 3.26 a. m.	566	do	5,043.55	8.9109
3.26 a. m. to 6.00 a. m.	154	Lying	789.13	5.1242
Subperiod 2—				
6.00 a. m. to 6.32 a. m.	32	do	158.28	4.9463
6.32 a. m. to 3.28 p. m.	536	Standing	3,920.78	7.3149
3.28 p. m. to 3.31 p. m.	3	Lying	15.29	5.4000
3.31 p. m. to 6.00 p. m.	149	Standing	1,065.11	7.1484
Subperiod 3—				
6.00 p. m. to 9.32 p. m.	212	do	1,676.98	7.9108
9.32 p. m. to 10.58 p. m.	86	Lying	426.64	4.9609
10.58 p. m. to 2.22 a. m.	204	Standing	1,646.90	8.0730
2.22 a. m. to 6.00 a. m.	218	Lying	971.14	4.4548

Heat emission—Continued.

Period and subperiod.	Time.	Position.	Total heat.	Heat per minute.
Period IV—Continued.				
Subperiod 4—	<i>Minutes.</i>		<i>Calories.</i>	<i>Calories.</i>
6.00 a. m. to 6.04 a. m.	4	Lying	22.82	5.7050
6.04 a. m. to 11.24 a. m.	320	Standing	2,516.92	7.8654
11.24 a. m. to 2.24 p. m.	180	Lying	893.35	4.9631
2.24 p. m. to 6.00 p. m.	216	Standing	1,672.97	7.7452

From the foregoing table have been computed the following results for the total heat produced during the several periods in the lying and the standing positions, respectively, together with the average heat emission per minute. In making these computations the artificial division into subperiods has been disregarded:

Total heat and average heat emission per minute.

Period.	Lying.	Standing.
Period I:		
Minutes	1,113	1,767
Total heat	5,127.63	12,652.21
Heat per minute.....	4.607	7.160
Ratio.....	1	1.554
Period II:		
Minutes	1,066	1,814
Total heat	4,248.90	10,668.25
Heat per minute.....	3.986	5.881
Ratio.....	1	1.476
Period III:		
Minutes	1,258	1,622
Total heat	5,034.68	10,340.01
Heat per minute.....	4.002	6.375
Ratio.....	1	1.593
Period IV:		
Minutes	677	2,203
Total heat	3,277.56	17,543.21
Heat per minute.....	4.841	7.963
Ratio.....	1	1.645

We should naturally ascribe these differences in heat emission to the increased muscular exertion required in standing. It will be noted, however, that the differences are much larger than those observed in the previous year with the same animal and are somewhat variable, the differences tending to be greater as the amount of food consumed increases. Moreover, as already noted, we are dealing only with the heat given off by radiation and conduction and not with the total heat emission. While, therefore, the above results are included for the sake of record, discussion of them is postponed until further data on this point shall have been accumulated.

HEAT EMISSION AND HEAT PRODUCTION.

The figures of the above tables show the amounts of heat given off by the animal. The heat emitted by the animal, however, is equal to the amount of heat actually produced only when the initial and final states of the animal are the same. Consequently there may be, according to circumstances, either a storage of heat in the body or an emission of heat produced in a previous period. In this respect there are two principal sources of error: first, variations in the body temperature of the animal; second, a storage or loss of matter by the body. As regards the first of these sources of error, it has been assumed that under normal and uniform conditions the body temperature would be substantially the same at the same hour of the day. We have not been able as yet to make systematic determinations of the body temperature of cattle as a check upon this assumption, but the rectal temperature of the animal was taken daily during the digestion periods proper of Periods I, II, III, and part of IV. The observations were made immediately before watering, by means of a mercurial thermometer, with the following results:

PERIOD I.		PERIOD III—Continued.	
Feb. 6.....	38.3° C.	Mar. 22.....	38.7° C.
7.....	38.1	22.....	38.5 (15 min. later)
8.....	38.2	22.....	38.1 (6 p. m.)
9.....	38.8	23.....	38.5
10.....	38.6	24.....	38.8 (after drinking)
11.....	38.6	24.....	38.2 (4.30 p. m.)
12.....	38.6	25.....	38.8
13.....	38.6	26.....	38.7
PERIOD II.		26.....	38.5 (15 min. later)
Feb. 27.....	38.5° C.	26.....	38.3 (1.50 p. m.)
28.....	38.5	26.....	38.5 (6 p. m.)
Mar. 1.....	38.6	27.....	38.6
2.....	38.6	27.....	38.8 (15 min. later)
3.....	38.4	27.....	38.6 (6 p. m.)
4.....	38.5	PERIOD IV.	
5.....	38.6	Apr. 10.....	38.7° C.
6.....	38.5	11.....	38.7
PERIOD III.		12.....	38.9
Mar. 20.....	38.5° C.	13.....	38.7
21.....	38.5		

Aside from the abnormally low temperatures of February 6, 7, and 8, the range of the observations taken under corresponding conditions is 38.4° C. to 38.9 C., and the greatest difference between two successive days is 0.2° C. With an average live weight of about 530 kilograms, assuming a specific heat of 1 for the body, this difference is equivalent to 106 Calories.

That the body temperature may be affected in particular by the consumption of water is rendered probable by the observations upon the rate of heat emission just considered as well as by those of the previous year. It is evident that for a time after drinking the average temperature of the animal plus the water drunk must be somewhat reduced, and the somewhat marked fall in the rate of heat emission after drinking, as shown in Diagram II, strongly suggests that this effect may continue for a considerable time. Our animal, however, was watered twelve hours before entering and leaving the calorimeter, and it seems reasonable to assume that his body temperature would be fully restored to the normal within that time.

If the animal stores up matter in its body, there must necessarily be a corresponding storing up of heat, since the matter which is stored was consumed in the food at a temperature considerably below that of the body. On the other hand, if there is a loss of matter from the body in any one of the various excreta, the temperature of this matter is reduced (either actually or by calculation) to that of the surrounding air before it leaves the calorimeter, and this heat which was previously stored up in the body is measured along with that actually produced during the experiment. The above statements are, of course, true, whatever be the kind of matter stored up or given off, but the income and outgo of water is of especial importance in this respect, both because of its large amount and because of the high specific heat of water. Indeed, a very simple calculation serves to show that in these experiments the difference in the income and outgo of dry matter does not materially affect the computation of the balance of energy, and that consequently only the income and outgo of water need be considered.

From the data contained in the various tables of the Appendix is compiled the following table, showing the income and outgo of water by the animal and the consequent gain or loss of heat on each day of the calorimeter experiments. The body temperature has been assumed to be 38.5°C ., while that of the calorimeter in every case was 18.2°C . In the case of feces spilled in the calorimeter, the water remaining in them when sampled has been divided equally between the two days. The amount of urine spilled has been calculated to the fresh weight upon the basis of its nitrogen content.

Approximate water balance.

Period.	Income.	Outgo.	Period.	Income.	Outgo.
Period I:			Period III:		
February 4—	<i>Grams.</i>	<i>Grams.</i>	March 18—	<i>Grams.</i>	<i>Grams.</i>
Hay	443	.....	Hay	319	.....
Water ^a	2,956	.....	Maize meal	115	.....
Uneaten residue		48	Water ^a	19,755	.....
Feces ^b		7,819	Feces ^b		4,705
Urine ^c		4,388	Feces, spilled		7
Water vapor		4,732	Urine ^c		4,936
Balance	13,588	.....	Water vapor		4,781
	16,987	16,987	Balance		5,760
February 5—				20,189	20,189
Hay	469	.....	March 19—		
Water ^a	16,345	.....	Hay	357	.....
Feces ^b		6,151	Maize meal	115	.....
Urine ^c		5,036	Water ^a	9,218	.....
Water vapor		4,477	Feces ^b		5,738
Balance		1,150	Feces, spilled		7
	16,814	16,814	Urine ^c		3,889
Period II:			Water vapor		4,855
February 25—			Balance	4,799	.....
Hay	250	.....		14,489	14,489
Water ^a	19,212	.....	Period IV:		
Uneaten residue		2	April 8—		
Feces ^b		3,082	Hay	313	.....
Urine ^c		3,587	Maize meal	549	.....
Water vapor		4,254	Water ^a	21,707	.....
Balance		8,537	Feces ^b		6,573
	19,462	19,462	Urine ^c		4,304
February 26—			Water vapor		7,472
Hay	296	.....	Balance		4,220
Water ^a	7,833	.....		22,569	22,569
Uneaten residue		2	April 9—		
Feces ^b		4,341	Hay	254	.....
Urine ^c		4,163	Maize meal	549	.....
Water vapor		4,560	Water ^a	17,595	.....
Balance	4,937	.....	Feces ^b		6,884
	13,066	13,066	Urine ^c		4,181
			Water vapor		8,134
			Balance	801	.....
				19,199	19,199

^a Including water used to moisten hay.^b Special sample.^c Assumed to contain the same percentage of solids as the mixed urine for the period.

Upon the basis of the above figures the actual heat production has been computed, as shown in the following table, the difference between the income and outgo of water, expressed in kilograms, being multiplied by 20.3, the difference in temperature, to obtain the correction.

Heat production.

Period.	Measured in calo- rimeter.	Correction for water.	Heat pro- duced.
	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
Period I:			
First day	11,688.75	-275.93	11,407.82
Second day	11,627.00	+ 23.35	11,650.35
Average	11,655.88	-126.29	11,529.09
Period II:			
First day	10,257.55	+173.30	10,430.85
Second day	9,915.48	-100.11	9,815.37
Average	10,086.52	+ 36.60	10,123.12
Period III:			
First day	10,290.38	+116.93	10,407.29
Second day	10,770.39	- 97.42	10,672.97
Average	10,530.38	+ 9.76	10,540.13
Period IV:			
First day	14,730.32	+ 85.67	14,815.99
Second day	14,504.04	- 16.28	14,487.78
Average	14,617.18	+ 34.70	14,651.88

THE BALANCE OF MATTER.

Considering the figures for epidermal tissues on page 16 to represent the average rate of growth of hair, etc., we may subdivide the gain or loss as ordinarily computed into the growth of these tissues and the real gain or loss of the proteids and fat in the body, as has been done in the computations which follow.

THE NITROGEN AND CARBON BALANCE.

The income and outgo of nitrogen and carbon are shown in the following table. The figures for hydrogen are omitted for the reason that, as stated on page 17, the results for water were not found to be satisfactory:

Income and outgo of nitrogen and carbon per day and head.

Period.	Nitrogen.		Carbon.	
	Income.	Outgo.	Income.	Outgo.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Period I:				
Hay	101.00		2,017.70	
Feces		48.20		879.60
Urine		74.97		150.46
Brushings		1.87		7.40
Methane				77.19
Carbon dioxide				1,186.40
Balance	19.04		283.35	
	120.04	120.04	2,301.05	2,301.05

Income and outgo of nitrogen and carbon per day and head—Continued.

Period.	Nitrogen.		Carbon.	
	Income.	Outgo.	Income.	Outgo.
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Period II:				
Hay.....	71.40		1,444.00	
Feces.....		28.40		617.10
Urine.....		58.50		103.43
Brushings.....		1.87		7.40
Methane.....				57.18
Carbon dioxide.....				1,003.90
Balance.....	17.37		345.01	
	88.77	88.77	1,789.01	1,789.01
Period III:				
Hay.....	78.80		1,435.90	
Maize meal.....	12.60		334.90	
Feces.....		33.20		661.40
Urine.....		59.01		125.31
Brushings.....		1.87		7.40
Methane.....				77.64
Carbon dioxide.....				1,103.90
Balance.....	2.68		204.85	
	94.08	94.08	1,975.65	1,975.65
Period IV:				
Hay.....	73.00		1,453.00	
Maize meal.....	60.90		1,578.70	
Feces.....		51.10		760.60
Urine.....		70.23		141.87
Brushings.....		1.87		7.40
Methane.....				136.91
Carbon dioxide.....				1,673.90
Balance.....		10.70		311.02
	133.90	133.90	3,031.70	3,031.70

GAIN OR LOSS OF PROTEIN AND FAT.

Excluding the amount of epidermal tissue produced, the gain or loss of protein and fat has been computed in the usual manner, using Köhler's^a figures for the composition of the nitrogenous tissue of cattle, namely, nitrogen 16.67 per cent and carbon 52.54 per cent. In other words, body protein is equivalent to nitrogen multiplied by 6. In the computation of fat from carbon the usual factor (1.3) has been employed.

Gain or loss of protein and fat per day and head.

Period.	Gain of nitrogen.	Equivalent protein N. × 6.	Gain of carbon.			Equivalent gain of fat.
			Total.	As protein.	As fat.	
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
I.....	-19.04	-114.24	-283.35	-60.02	-223.33	-290.33
II.....	-17.37	-104.22	-345.01	-54.76	-290.25	-377.33
III.....	-2.68	-16.08	-204.85	-8.45	-196.40	-255.32
IV.....	+10.70	+64.20	+311.02	+33.73	+277.29	+360.48

^a Zeit. physiol. Chem., v. 31, p. 479.

THE BALANCE OF ENERGY.

In these experiments we have direct determinations of all the factors of income and outgo of energy, except the potential energy of the methane excreted and that of the tissue gained by the animal. The energy of the methane, however, may be safely computed from its amount, its heat of combustion at constant pressure being 13,344 Calories per gram. The energy of the gain of tissue by the animal may be estimated in the usual way from the computed amounts of protein and fat given above, using the factors 5.7 Calories and 9.5 Calories per gram, respectively. Having done this we are in position to compare the income with the outgo of energy, and thus to check to a considerable extent the accuracy of our experiments. The following table contains such a comparison for each period. The difference between income and outgo, which has been entered in the table under the heading "Error," shows, of course, the extent to which our results appear to deviate from those required by the law of the conservation of energy. As noted on page 15, the figures for the urine are computed from its carbon content.

Balance of energy per day and per head.

	Income.	Outgo.
	<i>Calories.</i>	<i>Calories.</i>
Period I:		
Hay.....	19,840	
Feces.....		8,652
Urine (computed).....		1,505
Brushings.....		81
Methane.....		1,376
Heat.....		11,529
Loss by body—		
Protein.....	651	
Fat.....	2,758	
Error.....		106
	23,249	23,249
Period II:		
Hay.....	13,917	
Feces.....		5,838
Urine (computed).....		1,034
Brushings.....		81
Methane.....		1,020
Heat.....		10,123
Loss by body—		
Protein.....	594	
Fat.....	3,585	
	18,096	18,096
Period III:		
Hay.....	13,983	
Maize meal.....	3,203	
Feces.....		6,331
Urine (computed).....		1,253

Balance of energy per day and per head—Continued.

	Income.	Outgo.
	<i>Calories.</i>	<i>Calories.</i>
Period III—Continued.		
Brushings		81
Methane		1,384
Heat		10,540
Loss by body—		
Protein.....	92	
Fat.....	2,426	
Error.....		115
	19,704	19,704
Period IV:		
Hay	14,178	
Maize meal	15,066	
Feces.....		7,331
Urine (computed)		1,419
Brushings		81
Methane		2,441
Heat		14,652
Gain by body—		
Protein.....		366
Fat.....		3,425
Error.....	471	
	29,715	29,715

With the exception of Period IV, the agreement between the results computed from the balance of matter and those obtained by the direct determination of the heat evolved by the animal is very satisfactory. In Period IV the discrepancy is larger than it should be. The following table contains a comparison of the observed heat production with that computed by subtracting the energy of excreta plus gain from the energy of the food. It will be seen that the percentage error is relatively small in each period except in Period IV.

Heat production per day.

Period.	Computed.	Observed.	Computed ÷ observed.
	<i>Calories.</i>	<i>Calories.</i>	<i>Per cent.</i>
I.....	11,635	11,529	100.9
II.....	10,123	10,123	100.0
III.....	10,655	10,540	101.1
IV.....	14,181	14,652	96.8

DISCUSSION OF RESULTS.

DIGESTIBILITY.

Hay.—The results tabulated in Table III of the Appendix and summarized also under the several periods are brought together in the following table:

Percentage digestibility of hay.

Constituents and energy.	Period I.	Period II.
	<i>Per cent.</i>	<i>Per cent.</i>
Dry matter	59.18	59.70
Ash	46.29	46.48
Organic matter	60.00	60.61
Total protein ($N. \times 6.25$)	57.23	60.23
Proteids	48.58	53.19
Crude fiber	48.77	50.27
Nitrogen-free extract	69.90	68.94
Ether extract	65.36	65.02
Energy	56.39	58.05

It appears from the above figures that the digestibility of the hay was slightly greater in Period II, in which the smaller amount was fed, than in Period I. The results recorded in Bulletin 51, Bureau of Animal Industry, appear to show a marked increase of digestibility as the amount of hay consumed was diminished. Such difference as there is in the present instance is in the same direction, but it is so small as to be practically within the limits of error.

Maize meal.—The digestibility of the maize meal is computed in Table III of the Appendix upon the assumption that the hay fed in Periods III and IV was digested to the same extent as was the case in Period II, in which the same amount was fed. The results of the computation are as follows:

Computed percentage digestibility of maize meal.

Constituents and energy.	Period III.	Period IV.
	<i>Per cent.</i>	<i>Per cent.</i>
Dry matter	87.34	91.50
Ash		18.40
Organic matter	89.16	92.60
Total protein ($N. \times 6.25$)	85.23	62.30
Proteids	80.14	66.43
Crude fiber		32.40
Nitrogen-free extract	98.11	97.75
Ether extract	103.72	95.74
Energy	85.46	90.81

There is a very marked discrepancy in the results in the two periods, the maize meal appearing to have been more digestible in Period IV than in Period III, with the exception of protein, the difference falling largely upon the crude fiber. We are unable to explain the discrepancy. Since, however, the proportion of maize meal fed was much greater in Period IV than in Period III, any variation in the digestibility of the hay, or any other errors of experiment, will affect the final figures to a less degree, and we are inclined, therefore, to consider these figures as more nearly correct than those of Period III. The results obtained upon total protein and proteids seem to indicate a decrease in the apparent digestibility of these constituents under the influence of the large supply of carbohydrates in the maize meal.

METABOLIZABLE ENERGY.

The term metabolizable energy has been used by the writers to designate that portion of the total energy of the food which is capable of conversion into the kinetic form in the body. In this sense it is equivalent to energy of food minus energy of excreta, or to what is often called "fuel value."

The data of the foregoing pages enable us to compute the metabolizable energy of the rations in the several periods. Before doing so, however, a certain correction is necessary in the energy of the urine. For example, in Period I the animal lost 19.04 grams of body nitrogen, corresponding to a loss of 115.24 grams of protein. According to Rubner's results, the potential energy of the urine is increased by about 7.45 Calories for each gram of urinary nitrogen coming from the oxidation of body protein. In this case, then, the urine contained approximately $19.04 \times 7.45 = 142$ Calories of energy not derived from the potential energy of the food but from that of body tissue. It is plain, then, that the potential energy of the urine must be diminished by this amount before it is subtracted from the gross energy of the food in order to get the true metabolizable energy of the latter. The corresponding corrections for the several periods, computed in this way, are as follows:

Corrected energy of urine.

Period.	Gain of nitrogen.	Equivalent energy.	Corrected energy of urine.
	<i>Grams.</i>	<i>Calories.</i>	<i>Calories.</i>
I.....	-19.04	-142	1,363
II.....	-17.37	-129	905
III.....	- 2.68	- 20	1,233
IV.....	+10.70	+ 80	1,499

Hay.—The data of Periods I and II enable us to compute the metabolizable energy of the clover hay fed, as shown in the following table:

Metabolizable energy of clover hay.

Feed and excreta.	Period I.		Period II.	
	Feed.	Excreta.	Feed.	Excreta.
	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
Hay.....	19,840	.....	13,917	.....
Feces.....	.....	8,652	.....	5,838
Urine (corrected).....	.....	1,363	.....	905
Methane.....	.....	1,376	.....	1,020
Metabolizable.....	.....	8,449	.....	6,154
Total.....	19,840	19,840	13,917	13,917

The relation of the metabolizable energy to the amount of matter in the food may be expressed in terms of Calories per gram of the total or of the digested organic matter. Computed in this way the results are as shown in the table following:

Metabolizable energy per gram of organic matter of clover hay.

Period.	Organic matter of rations.		Metabolizable energy.		
	Total.	Digested.	Total.	Per gram of total organic matter.	Per gram of digested organic matter.
	<i>Grams.</i>	<i>Grams.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
I.....	4,174	2,505	8,449	2.024	3.373
II.....	2,941	1,783	6,154	2.092	3.452

The metabolizable energy of a feeding stuff may also be expressed as a percentage of the total or gross energy. Such a percentage is analogous to a digestion coefficient, so that if an average value for it were established for any particular kind of feeding stuff, the amount of metabolizable energy in a given amount of it could be computed from its total energy by multiplication by this coefficient just as the digestible dry matter or organic matter can be computed from the total amount present by the use of a digestion coefficient. The first half of the following table shows the percentage of the total energy which escaped in the several excreta or which was metabolized in the animal's body, while the second half of the table shows the same relations based upon the energy of the digested matter:

Distribution of energy of clover hay.

Energy—	Total energy.			Energy of digested matter.		
	Period I.	Period II.	Average.	Period I.	Period II.	Average.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
In feces	43.61	41.95	42.78	.....	.....	.....
In urine	6.87	6.50	6.69	12.18	11.20	11.69
In methane	6.94	7.33	7.13	12.30	12.62	12.46
Metabolizable	42.58	44.22	43.40	75.52	76.18	75.85
Total	100.00	100.00	100.00	100.00	100.00	100.00

Maize meal.—In Periods III and IV, in which maize meal was fed, the total metabolizable energy of the ration was as shown in the following table:

Metabolizable energy of total ration.

Feed and excreta.	Period III.		Period IV.	
	Feed.	Excreta.	Feed.	Excreta.
	Calories.	Calories.	Calories.	Calories.
Hay	13,983	.....	14,178	.....
Maize meal	3,203	.....	15,066	.....
Feces .....	.....	6,331	.....	7,331
Urine (corrected) .....	.....	1,233	.....	1,499
Methane .....	.....	1,384	.....	2,441
Metabolizable .....	.....	8,238	.....	17,973
Total	17,186	17,186	29,244	29,244

A part of the metabolizable energy shown in the above table, however, was derived from the hay and only part from the maize meal. Knowing, however, the amount of gross energy contained in the hay consumed, we can apply to this the percentages computed in the previous table and compute how much of the energy of the hay was lost in the excreta and how much was metabolizable. For this purpose the results upon Period II have been used, this being the period in which the same amount of hay was fed as in Periods III and IV. The computation is precisely similar in principle to the computation of the digestibility of grain in a mixed ration. The results are contained in the following table:

Computed metabolizable energy of maize meal.

	Organic matter.		Total energy.	Energy of excreta.			Metabolizable energy.
	Total.	Digestible.		Feces.	Urine (corrected).	Methane.	
	Grams.	Grams.	Calories.	Calories.	Calories.	Calories.	Calories.
Period III:							
Total ration	3,676.6	2,435.1	17,186	6,331	1,233	1,384	8,238
Clover hay	2,952.8	1,789.7	13,983	5,866	909	1,025	6,183
Maize meal	723.8	645.4	3,203	465	324	359	2,055
Period IV:							
Total ration	6,375.6	4,952.3	29,244	7,331	1,499	2,441	17,973
Clover hay	2,974.8	1,803.0	14,178	5,948	922	1,039	6,269
Maize meal	3,400.8	3,149.3	15,066	1,383	577	1,402	11,704

Computing these results per gram of total or digested organic matter, and computing also the percentage distribution of the total energy as in the case of hay, we have the following:

Metabolizable energy per gram of organic matter in maize meal.

Period.	Organic matter of maize meal.		Metabolizable energy of maize meal.		
	Total.	Digested.	Total.	Per gram of total organic matter.	Per gram of digested organic matter.
	Grams.	Grams.	Calories.	Calories.	Calories.
III.....	724	645	2,055	2.838	3.186
IV.....	3,401	3,149	11,704	3.441	3.716

Distribution of energy of maize meal.

	Total energy.		Energy of digested matter.	
	Period III.	Period IV.	Period III.	Period IV.
	Per cent.	Per cent.	Per cent.	Per cent.
In feces.....	14.52	9.18	.....	.....
In urine.....	10.12	3.83	11.83	4.22
In methane.....	11.20	9.31	13.11	10.25
Metabolizable.....	64.16	77.68	75.06	85.53
	100.00	100.00	100.00	100.00

The results in these two periods show a very considerable divergence. The low percentage digestibility of the maize meal in Period III is equivalent, of course, to a greater apparent loss of energy in the feces and therefore to a lower percentage of metabolizable energy. Even when this is eliminated, however, by making the computation upon the energy of the digested matter we still find a marked difference, Period III showing a greater loss in the methane, and particularly in the urine. While the outcome is unsatisfactory, it would seem that the results in Period IV are likely to be nearer the truth than those of Period III.

The above results represent what has been called the "apparent" metabolizable energy. It is not at all unlikely that the addition of maize meal affected to a greater or less degree the digestibility of the hay to which it was added. In particular, as was pointed out on page 33, it seems possible that it diminished the digestibility of the protein of the total ration. If such was the case the results obtained above are too small to represent the actual metabolizable energy of maize meal, just as the corresponding results upon the digestibility of the protein are too small. In the one case as in the other our figures represent the net effect upon the amount of metabolizable energy or of protein which the animal derived from its ration. Any effect of

one ingredient of the ration upon the digestibility of the other is ascribed, by the method of computation employed, entirely to the maize meal. The results, therefore, as stated, represent the apparent digestibility or the apparent metabolizable energy.

COMPARISON OF RESULTS.

On account of the apparent variation in digestibility the results upon metabolizable energy are not very satisfactory, and the same was the case with the experiment of the previous year. Nevertheless, it may be of some interest to compare the data obtained for the various materials experimented with. In making this comparison the results for timothy hay obtained by comparing Periods A and C have been employed.^a For clover hay the average of Periods I and II is used, and for maize meal the results of Period IV. Kellner's^b average figures for German meadow hay have also been included.

Percentage metabolizable.

Feeds.	Of total energy.	Of energy of digested matter.
	<i>Per cent.</i>	<i>Per cent.</i>
Timothy hay.....	44.25	^a 86.58
Clover hay.....	43.40	75.85
Meadow hay.....	46.56	78.77
Maize meal.....	77.68	85.53

^a Erroneously given in Bureau of Animal Industry, Bul. 51 as 85.58 per cent.

Computed on the basis of total energy the maize meal naturally gives much higher figures because of its greater digestibility. Of the three coarse fodders the German meadow hay gives the highest results and the clover hay the lowest. The figures for the distribution of energy contained in the next following table show that the larger losses of energy in the case of clover hay as compared with meadow hay are partly due to inferior digestibility, and in part to larger losses in the urine and methane. In the case of timothy hay, while the digestibility is lower than that of either of the other two, the relatively small losses in urine and methane bring the percentage of metabolizable energy above that for the clover hay. When the computation is made upon the energy of the digested matter these relatively small losses in urine and methane result in a relatively high figure for metabolizable energy, the digested matter of the timothy hay not only being superior to that of the clover hay and meadow hay in this respect but even showing a slightly higher value than the digestible matter of maize meal.

^a Bureau of Animal Industry, Bul. 51, p. 52.

^b Landw. Vers. Stat., v. 53, p. 447.

Percentage distribution of energy.

	Total energy.				Energy of digested matter.			
	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
In feces	48.90	42.78	40.96	9.18	.....	.....	.....	.....
In urine	3.06	6.69	5.71	3.83	6.00	11.69	9.66	4.22
In methane.....	3.79	7.13	6.77	9.31	7.42	12.46	11.57	10.25
Metabolizable	44.25	43.40	46.56	77.68	86.58	75.85	78.77	85.53
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

NET AVAILABLE ENERGY.

Both our own observations and those of others, notably those of Zuntz and his associates, have shown that a considerable portion of the metabolizable energy of the food may be consumed in those mechanical and chemical processes incident to the digestion of the food and its conversion into forms fitted to nourish the body, or may otherwise be converted into the form of heat, and so not be directly available to make good the losses of potential energy from the body caused by the vital processes. The portion of the metabolizable energy remaining after subtracting the portion thus expended represents the net contribution which the food has made to the maintenance of the stock of potential energy in the body. This portion of the energy of the food is designated as net available energy.^a The availability of the energy of a food may be determined by adding the substance in question to a known basal ration and determining the extent to which the added food diminishes the previous loss of tissue. Such a comparison may be based either upon the total energy of the food or upon its metabolizable energy, but the latter seems the more appropriate of the two.

As the balance of energy on pages 28 and 29 shows, however, the gain or loss as computed from the nitrogen and carbon balance does not exactly agree with that computed from the difference between income and outgo of energy. For the present purpose it seems most satisfactory to use the average of these results, or, in other words, to substitute in the balance of energy the average of the computed and the observed heat production as given on page 31. For example, in Period I we obtain the following as the average loss of energy in the form of protein and fat:

^a Kellner (Ernährung landw. Nutzthiere, p. 104) designates these two portions into which the metabolizable energy of the food may be divided as "Thermic energy" and "Dynamic energy," respectively.

Average loss of energy.

Feed, excreta, etc.	Income.	Outgo.
	<i>Calories.</i>	<i>Calories.</i>
Hay.....	19,840	.....
Feces.....	.....	8,652
Urine, corrected.....	.....	1,505
Brushings.....	.....	81
Methane.....	.....	1,376
Average heat production.....	.....	11,582
Computed loss of protein and fat.....	3,356	.....
Total.....	23,196	23,196

In making the comparison with the metabolizable energy, however, the loss of tissue as thus computed must be corrected by subtracting 7.45 Calories for each gram of nitrogen in the urine, since the amount of metabolizable energy was corrected in the same way. The average figures for the growth of epithelial tissue must also be counted as part of the gain. Making these corrections, we have the following results for the several periods, those for Period IV being computed both on the basis of the observed and of the computed heat production as well as upon the average, as in other cases:

Average gain or loss.

Period.	Average gain or loss of protein and fat.	Growth of epithelial tissue.	Correction for nitrogen.	Total gain or loss.
	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
I.....	-3,356	+81	+142	-3,133
II.....	-4,179	+81	+129	-3,969
III.....	-2,461	+81	+20	-2,360
IV (based on observed heat production).....	+3,320	+81	-80	+3,321
IV (based on computed heat production).....	+3,791	+81	-80	+3,792
IV (average).....	+3,555	+81	-80	+3,556

The results in the above table are also shown graphically in Diagram III, in which the abscissæ represent the total amounts of metabolizable energy supplied to the animal, and the ordinates the resulting gain or loss of energy.

AVAILABLE ENERGY OF HAY.

A comparison of Periods I and II, in which different amounts of hay were fed, affords the means of determining the availability of the metabolizable energy of the latter, the results for Period II being subtracted from those for Period I, as in the table following.

Availability of energy.

Period.	Organic matter.		Metabolizable energy.	Gain.	Availability.
	Total.	Digested.			
	Grams.	Grams.	Calories.	Calories.	Per cent.
I.....	4,174	2,505	8,449	-3,133	.....
II.....	2,941	1,783	6,154	-3,969	.....
Difference	1,233	722	2,295	836	36.42

From the above table it appears that the 2,295 additional Calories of metabolizable energy supplied in Period I diminished the loss of energy from the body by 836 Calories. The latter figure represents the portion of the added metabolizable energy which was available in the sense in which that term is here used, and is 36.42 per cent of the 2,295 Calories of added energy. The availability is indicated in Diagram III by the line AB. The above figures show a comparatively low availability for clover hay, particularly as compared with timothy hay, for which a percentage of 62.92 was found, and, pending further experiments, must be accepted with considerable reserve.

AVAILABLE ENERGY OF MAIZE MEAL.

The availability of the energy of the maize meal may be computed by a comparison of Periods II and III upon precisely the same principle as that just made between Periods I and II. Owing, however, to slight variations in the percentage of moisture contained in the hay, the animal actually ate 18.9 grams more dry matter of hay in Period III than in Period II, an amount which is equivalent to 66.2 Calories of total energy. On the average of Periods I and II, 43.4 per cent of this total energy was metabolizable, or 29 Calories; and 36.42 per cent of the latter amount, equivalent to 10 Calories, was, according to the figures just given, available. In other words, if only as much hay had been consumed in Period III as in Period II, the metabolizable energy would have been less by 29 Calories and the gain less by 10 Calories. Making this correction, we have the results shown in the following table:

Percentage availability of maize meal.

	Metabolizable energy.	Gain.	Percentage availability.
	Calories.	Calories.	Per cent.
Total, Period III	8,238	-2,360	.....
Correction for hay.....	-29	-10	.....
Period II	8,209	-2,370	.....
	6,154	-3,969	.....
Difference	2,055	1,599	77.81

These results are indicated in Diagram III by the line AC.^a

While this result is subject to the errors involved in the determination of the metabolizable energy of the maize meal, it is nevertheless evident that the energy of the latter is far more available than is that of either clover or timothy hay. Expressed in another way, this is equivalent to saying that the expenditure of energy in digestion and assimilation is relatively less in the case of maize meal, a result which was to have been anticipated from the nature of the material. Even if we compute the metabolizable energy of the maize meal with the aid of the data obtained in Period IV, we still find an availability of 76.2 per cent.

REPLACEMENT VALUES.

The earlier investigations of Rubner upon the replacement values of the nutrients, and his theory of isodynamic replacement founded upon them, have led many writers to regard the so-called "fuel value" of nutrients and feeding stuffs as a measure of their value in nutrition, at least for purposes of maintenance. By the term "fuel value," equivalent to what we have here called metabolizable energy, is meant the amount of heat which the material is capable of liberating in the body when oxidized to the final excretory products, and the tacit assumption is that, since on a maintenance ration all the energy of the food finally leaves the body in the form of heat, the fuel value of a feeding stuff is equivalent to its nutritive value.

Our results upon timothy hay,^b however, showed that about 37 per cent of the metabolizable energy of this feeding stuff served simply to increase the heat production of the animal, while only the remaining 63 per cent were available to replace that lost by the katabolism of body tissue. In other words, the digestible organic matter of the hay was not isodynamic with body tissue. It was there pointed out that in all probability the availability of the metabolizable energy of different feeding stuffs would be found to differ, particularly in the case of grain as compared with coarse fodder, and that therefore the relative values of different feeding stuffs for maintenance would not be proportional to their metabolizable energy, or "fuel value."

The results of the present series of experiments fully confirm this anticipation. From the data on the foregoing pages we find the metabolizable energy of one kilogram of total organic matter to be as follows:

Metabolizable energy per kilogram of total organic matter.

	Calories.
Clover hay (average of Periods I and II).....	2,058
Timothy hay (Periods C-A).....	2,113
Maize meal (Period IV).....	3,441

^a The slight correction for hay is not shown on the diagram.

^b Bureau of Animal Industry, Bulletin No. 51, pp. 61-63.

The extent to which one kilogram of total organic matter diminished the loss of body tissue—i. e., its actual value for maintenance—is measured by its available energy, and was as follows:

Available energy per kilogram of total organic matter.

	Calories.
Clover hay.....	750
Timothy hay.....	1,330
Maize meal.....	2,678

Taking clover hay as unity, the relative maintenance values of one kilogram of total organic matter as computed from its metabolizable energy (fuel value) and as actually measured by its available energy were as follows:

Relative values of total organic matter for maintenance.

Feeds.	Computed from metabolizable energy.	Computed from available energy.
Clover hay.....	1.000	1.000
Timothy hay.....	1.027	1.773
Maize meal.....	1.672	3.571

A similar comparison per kilogram of digestible organic matter gives the following result:

Energy per kilogram, digestible organic matter.

Feeds.	Metabolizable.	Available.
	Calories.	Calories.
Clover hay.....	3,413	1,243
Timothy hay.....	3,794	2,387
Maize meal.....	3,716	2,892

Relative values of digestible organic matter for maintenance.

Feeds.	Computed from metabolizable energy.	Computed from available energy.
Clover hay.....	1.000	1.000
Timothy hay.....	1.112	1.920
Maize meal.....	1.089	2.325

It is evident that the maintenance values based on the fuel values are not only much too high, but are not even approximately correct relatively.

PERCENTAGE UTILIZATION OF ENERGY.

In Period IV enough maize meal was added to the ration to cause a material gain by the animal. The percentage of metabolizable energy actually stored as gain may be designated as the percentage utilization in distinction from the percentage availability, which is measured

by the diminution of the loss below the maintenance requirement. As we have seen, a certain percentage of the metabolizable energy of the food is expended in its digestion and assimilation. When, however, this assimilated food is to be converted into tissue, we may assume as altogether probable that additional chemical work must be done upon it, involving a further expenditure of energy. If this is the case, we shall expect to find the percentage utilization correspondingly less than the percentage availability.

In Period IV slightly more hay was consumed than in Period III. After correcting for this, as in the previous case, the subtraction of Period III from Period IV shows that in the latter 9,639 Calories more of metabolizable energy were consumed, resulting in a gain of 3,525

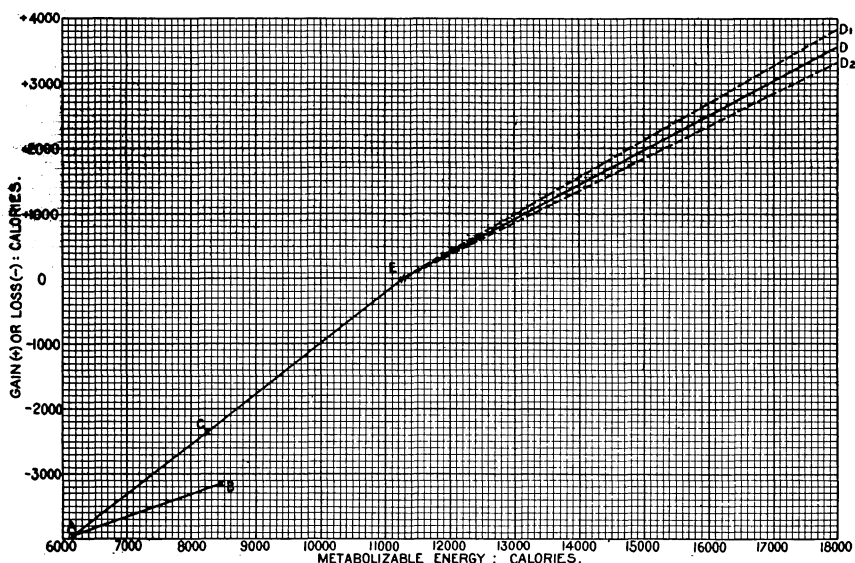


DIAGRAM III.—Availability and utilization of energy.

Calories instead of a loss of 2,360 Calories. The effect of the added 9,639 Calories, therefore, is a mixed one, namely, preventing a loss of 2,360 Calories, and causing an actual gain of 3,525 Calories. From these figures it is not possible to compute directly the percentage availability or the percentage utilization. If, however, we assume that the availability of the energy is independent of the amount fed, we can easily compute how much maize meal it would have been necessary to add to the ration of Period III to exactly reach the maintenance requirement. Obviously 2,360 Calories of available energy would be required for this purpose. We have already computed the availability to be 77.81 per cent. The required amount of metabolizable energy, therefore, is $2,360 \div 0.7781 = 3,033$ Calories. Geometrically, this operation is represented in Diagram III by the production

of the line AC to E. Subtracting this amount from the total difference between the two periods we find, as shown in the table, that there remained 6,604 Calories of metabolizable energy which produced an average gain of 3,525 Calories, corresponding to a percentage utilization of 53.30 per cent, which is represented by the line ED in Diagram III. In the last two columns of the table are included also the results based respectively upon the maximum and minimum figures for the gain as given on page 39, the corresponding lines in the diagram being the broken lines ED₁ and ED₂.

Percentage utilization.

	Metabolizable energy.	Gain.		
		Average.	Maximum.	Minimum.
	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
Period IV	17,973	3,556	3,792	3,321
Correction for hay	-86	-31	-31	-31
Period IV, corrected	17,887	3,525	3,761	3,290
Period III	8,238	-2,360	-2,360	-2,360
Difference	9,649	5,885	6,121	5,650
Maize meal required to reach maintenance	3,033	2,360	2,360	2,360
	6,616	3,525	3,761	3,290
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Percentage utilization		53.28	56.85	49.73

Clearly the percentage utilization is much less than the percentage availability, even if we take the lower corrected figures for the latter. Of the net available energy supplied 31.52 per cent appears to have been expended in the work of tissue building, while 64.48 per cent was stored as gain. This result is quite in accordance with the indications obtained in Period D of the previous year's experiments on timothy hay (*idem*, pp. 58 and 64.)

DISTRIBUTION OF ENERGY.

The foregoing results, and those of Bulletin No. 51, Bureau of Animal Industry, afford data for at least an approximate comparison of the percentage distribution of the energy of timothy hay, clover hay, and maize meal between the several excretory products, the expenditure in digestion and assimilation, the expenditure in tissue formation, and the resulting gain of tissue. The results are contained in the tables following, which are an extension of that given on page 38. The distribution is calculated both upon the total energy and upon the energy of the digested matter. Kellner's average results for German meadow hay are also included in the table for the sake of comparison.

Percentage distribution of total energy.

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
In feces	48.90	42.78	40.96	9.18
In urine.....	3.06	6.69	5.71	3.83
In methane	3.79	7.13	6.77	9.31
Expended in digestion and assimilation.....	16.41	27.60	27.28	17.23
Expended in tissue formation	13.10	15.80		19.06
Stored as gain.....	14.74		19.28	41.39
	100.00	100.00	100.00	100.00
Net available	27.84	15.80	.....	60.45

Percentage distribution of energy of digested matter.

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
In urine	6.00	11.69	9.66	4.22
In methane.....	7.42	12.46	11.57	10.25
In digestion and assimilation	32.10	48.24	46.08	18.97
In tissue formation	25.64	27.61		20.99
Stored as gain	28.84		32.69	45.57
	100.00	100.00	100.00	100.00
Net available	54.49	27.61	.....	65.55

The same results may also be computed in Calories per unit of dry matter, using the percentages of the above tables as coefficients. The total or gross energy of the materials, taking in case of timothy hay, clover hay, and maize meal the average of the two general samples, was as follows:

Total or gross energy of materials.

Materials.	Per kilogram dry matter.	Per kilogram digested organic matter.
	<i>Calories.</i>	
Timothy hay	4,554	^a 4,382
Clover hay	4,457	^b 4,494
Maize meal	4,431	^c 4,327
German meadow hay	4,413	4,437

^a Preliminary period, steer No. 1.^b Average of Periods I and II.^c Average of Periods III and IV.

On this basis have been computed the figures of the table following, showing the total energy per kilogram of dry matter and its distribution in accordance with the percentage figures already given.

Energy per kilogram total dry matter.

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
Lost in feces.....	2,227	1,907	1,807	407
Lost in urine.....	139	298	252	170
Lost in methane.....	173	318	299	413
Expended in digestion and assimilation.....	747	1,230	1,204	763
Expended in tissue formation.....	597	704			844
Stored as gain.....	671		851	1,834
Total.....	4,554	4,457	4,413	4,431
Available for maintenance.....	1,268	704	.....	2,679

Energy per kilogram digestible organic matter.

	Timothy hay.	Clover hay.	Meadow hay.	Maize meal.
	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>	<i>Calories.</i>
Lost in urine.....	262	525	429	183
Lost in methane.....	325	560	513	443
Expended in digestion and assimilation.....	1,407	2,168	2,045	821
Expended in tissue formation.....	1,124	1,241			908
Stored as gain.....	1,264		1,450	1,972
Total.....	4,382	4,494	4,437	4,327
Available for maintenance.....	2,388	1,241	.....	2,880

Taking the figures for timothy hay as 1.00, the relative values of these four feeding stuffs are as follows:

Relative values.

Foods.	Per kilogram total dry matter.		Per kilogram digestible organic matter.	
	For main-tenance.	For fatten-ing.	For main-tenance.	For fatten-ing.
Timothy hay	1.00	1.00	1.00	1.00
Clover hay.....	.56	.....	.52	.....
Meadow hay .....	.....	1.27	.....	1.15
Maize meal	2.11	2.73	1.21	1.56

These figures again render it evident that neither the maintenance value nor the value for productive purposes of these feeding stuffs is proportional to their metabolizable energy (fuel value).

It must, of course, be remembered that the above figures, with the exception of Kellner's average for meadow hay, are the results of but a single experiment each upon one animal. It is scarcely necessary to say that far more extensive investigations are necessary to secure results which can be regarded as fixing the absolute values of these

three feeding stuffs for maintenance or for productive purposes. We are far from making the general statement that one kilogram of the dry matter of timothy hay, for example, is capable of producing a gain of 671 Calories by a steer, or that it has a value of 1,268 Calories in a maintenance ration.

The value of our results, in our judgment, lies in the very marked differences which they show between the "fuel value," the value for maintenance, and the value for productive purposes. These differences appear to us too large to be accounted for by the possible errors of single experiments, and we therefore believe that our results constitute at least a qualitative demonstration of the existence of such differences, especially since they are entirely in harmony in this respect with those of other investigators, and with generally accepted conceptions of the physiology of nutrition.



APPENDIX.

TABLE I.—*Weight, water drunk, and excreta.*

For 24 hours ended on date given.	Live weight.	Water drunk.	Feces.	Urine. ^a	For 24 hours ended on date given.	Live weight.	Water drunk.	Feces.	Urine. ^a
<i>Hay only.</i>					<i>Hay only—Con.</i>				
Period I:					Period II:				
Jan., 1903.	<i>Kilos.</i>	<i>Kilos.</i>	<i>Grams.</i>	<i>Grams.</i>	Feb., 1903.	<i>Kilos.</i>	<i>Kilos.</i>	<i>Grams.</i>	<i>Grams.</i>
24.....	577.5	0.0	.....	.....	14.....	543.9	0.0	.....	.....
25.....	559.8	22.45	.....	.....	15.....	529.8	25.95	.....	.....
26.....	566.6	18.6	.....	.....	16.....	540.8	1.4	.....	.....
27.....	565.2	3.8	.....	.....	17.....	527.7	18.3	.....	.....
28.....	553.1	28.1	.....	.....	18.....	534.25	0.0	.....	.....
29.....	561.0	8.0	.....	.....	19.....	521.0	30.2	.....	.....
30.....	553.4	18.0	.....	.....	20.....	536.4	5.8	.....	.....
31.....	554.0	0.0	.....	.....	21.....	526.6	17.7	.....	.....
Feb., 1903.					22.....	532.4	0.0	.....	.....
1.....	541.5	31.8	.....	.....	23.....	520.25	16.55	.....	.....
2.....	556.2	0.0	.....	.....	24.....	b[527.0]	0.0	.....	.....
3.....	b[545.9]	24.05	.....	.....	25.....	.....	13.0	4,058	3,840
4.....	.....	2.5	9,738	4,730	26.....	c[524.9]	7.565	5,713	4,457
5.....	c[554.0]	16.1	7,793	5,433	27.....	b[519.4]	25.6	5,712	7,003
6.....	b[549.5]	10.9	9,430	5,371	28.....	523.4	11.8	6,942	e[7,577]
7.....	540.5	24.1	8,500	5,502	Mar., 1903.				
8.....	548.1	13.0	9,545	d[5,625]	1.....	520.8	16.8	4,588	6,365
9.....	545.4	12.8	10,705	6,283	2.....	524.2	9.8	7,895	6,300
10.....	543.0	20.9	8,652	6,238	3.....	518.2	15.5	5,569	7,033
11.....	548.6	10.85	8,975	6,015	4.....	520.2	0.0	6,438	4,160
12.....	544.0	12.2	9,195	6,290	5.....	512.0	24.2	4,960	3,963
13.....	540.0	18.0	9,344	6,050	6.....	523.0	0.0	4,727	5,830
Total.....	.....	.....	91,677	57,537	Total.....	.....	.....	56,602	48,951
Spilled in calorimeter.....	.....	.....	19.5	.....	Spilled in calorimeter.....	.....	.....	19.4	.....
Spilled in stall.....	.....	.....	.....	.....	Spilled in stall.....	.....	.....	.....	.....
Feb. 13.....	.....	.....	1.6	.....	Mar. 1.....	.....	.....	.....	58.8

^a Including wash water.

^b Taken at 7.30 a. m.

^c Taken at 6.00 p. m., when removed from calorimeter.

^d Very small loss of urine.

^e Not composited—considerable loss.

TABLE I.—*Weight, water drunk, and excreta*—Continued.

For 24 hours ended on date given.	Live weight.	Water drunk.	Feces.	Urine. ^a	For 24 hours ended on date given.	Live weight.	Water drunk.	Feces.	Urine. ^a
<i>Hay and maize meal.</i>					<i>Hay and maize meal—Con.</i>				
Period III:					Period IV:				
Mar., 1903.	<i>Kilos.</i>	<i>Kilos.</i>	<i>Grams.</i>	<i>Grams.</i>	Mar. 1903.	<i>Kilos.</i>	<i>Kilos.</i>	<i>Grams.</i>	<i>Grams.</i>
7.....	536.6	25.1	.....	.....	28.....	507.0	10.8	.....	.....
8.....	524.8	3.3	.....	.....	29.....	514.2	25.6	.....	.....
9.....	515.2	0.0	.....	.....	30.....	526.0	11.8	.....	.....
10.....	503.4	29.8	.....	.....	31.....	521.8	23.8	.....	.....
11.....	519.8	21.0	.....	.....	Apr. 1.....	530.6	5.6	.....	.....
12.....	523.6	14.4	.....	.....	2.....	527.4	24.8	.....	.....
13.....	520.6	14.7	.....	.....	3.....	533.0	13.8	.....	.....
14.....	519.9	14.3	.....	.....	4.....	526.0	18.0	.....	.....
15.....	519.8	9.4	.....	.....	5.....	527.0	0.0	.....	.....
16.....	513.8	22.8	.....	.....	6.....	511.2	34.0	.....	.....
17.....	<i>b</i> [526.8]	0.0	.....	.....	7.....	<i>b</i> [534.0]	0.0	.....	.....
18.....	.....	19.355	5,875	5,235	8.....	.....	20.907	7,993	4,627
19.....	<i>c</i> [519.9]	8.818	7,167	4,125	9.....	<i>c</i> [532.65]	16.795	8,435	4,495
20.....	<i>b</i> [515.0]	20.1	7,169	5,368	10.....	<i>b</i> [524.2]	24.9	6,018	6,020
21.....	516.5	13.7	6,915	6,950	11.....	524.0	21.2	8,955	4,720
22.....	515.0	24.2	7,070	8,485	12.....	528.2	25.9	10,560	5,925
23.....	521.1	0.0	7,947	<i>d</i> [8,610]	13.....	534.0	15.3	7,392	6,130
24.....	505.4	33.0	5,868	8,408	14.....	530.3	20.8	9,710	5,578
25.....	522.2	0.0	6,710	7,315	15.....	534.3	16.8	9,350	5,195
26.....	506.4	23.9	7,360	9,025	16.....	533.2	16.0	9,350	6,110
27.....	514.6	13.0	5,925	6,565	17.....	533.3	19.0	9,000	5,885
Total.....	.....	.....	68,006	70,086	Total.....	.....	.....	86,763	54,685
Spilled in calorimeter	.....	.....	.....	.....	Dung in tube at end of period.....	.....	.....	383.6	.....
Mar. 19.....	.....	.....	29.0	.....	Spilled in stall	.....	.....	.....	.....
Spilled in stall:	.....	.....	.....	.....	Apr. 13.....	.....	.....	.....	50
Mar. 20.....	.....	.....	45.9	.....					
Mar. 22.....	.....	.....	78.2	.....					
Mar. 8.....	.....	.....	8.4	.....					
Mar. 9.....	.....	.....	10.6	.....					

^a Including wash water.^b Taken at 7.30 a. m.^c Taken at 6.00 p. m., when removed from calorimeter.^d Very small loss of urine.

TABLE II.—*Composition of dry matter of feces.*

Constituents and energy.	Hay only.		Hay and maize meal.	
	Period I.	Period II.	Period III.	Period IV.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Ash	8.41	8.58	9.22	9.77
Protein (N×6.25).....	14.81	14.01	15.20	20.24
Crude fiber.....	42.46	41.54	40.90	36.02
Nitrogen-free extract	31.86	33.53	32.46	31.55
Ether extract	2.46	2.34	2.22	2.42
	100.00	100.00	100.00	100.00
Total nitrogen	2.371	2.240	2.431	3.239
Proteid nitrogen.....	2.079	1.933	2.122	2.390
Carbon.....	48.27	48.70	48.36	48.22
Hydrogen.....	5.97	6.04	6.19	6.54
	<i>Calories per gram.</i>	<i>Calories per gram.</i>	<i>Calories per gram.</i>	<i>Calories per gram.</i>
Heat of combustion.....	4,747.6	4,607.5	4,629.6	4,647.4

TABLE III.—*Digestibility of rations.*

	Dry matter.	Ash.	Organic matter.	Proteids.	Non-proteids.	Crude fiber.	Nitrogen-free extract.	Ether extract.	Nitrogen.	Carbon.	Energy.
<i>Total rations.</i>											
Period I:	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grams.</i>	<i>Cals.</i>
Hay	4,459.0	285.4	4,173.6	524.7	80.7	1,510.4	1,928.6	129.2	101.0	2,017.7	19,839.9
Feces	1,822.3	153.3	1,669.0	269.9	.....	773.8	580.6	44.8	43.2	879.6	8,651.6
Digested.....	2,636.7	132.1	2,504.6	254.8	80.7	736.6	1,348.0	84.4	57.8	1,138.1	11,188.3
Coefficient, p. ct.	59.13	46.29	60.00	48.58	100.00	48.77	69.90	65.36	57.23	56.41	56.39
Period II:											
Hay	3,143.9	203.1	2,940.8	379.2	50.3	1,058.5	1,367.9	84.9	71.4	1,444.0	13,916.5
Feces	1,267.0	108.7	1,158.3	177.5	.....	526.4	424.9	29.7	28.4	617.1	5,837.7
Digested.....	1,876.9	94.4	1,782.5	201.7	50.3	532.1	943.0	55.2	43.0	826.9	8,078.8
Coefficient, p. ct.	59.70	46.48	60.61	53.19	100.00	50.27	68.94	65.02	60.23	57.27	58.05
Period III:											
Hay	3,162.8	210.0	2,952.8	414.6	59.1	995.6	1,393.2	90.1	78.8	1,435.9	13,982.7
Maize meal.....	734.7	10.9	723.8	69.5	5.0	17.5	601.7	30.1	12.6	334.9	3,203.1
Total	3,897.5	220.9	3,676.6	484.1	64.1	1,013.1	1,994.9	120.2	91.4	1,770.8	17,185.8
Feces	1,367.6	126.1	1,241.5	207.9	.....	559.3	443.9	30.4	33.2	661.4	6,331.4
Digested.....	2,529.9	94.8	2,435.1	276.2	64.1	453.8	1,551.0	89.8	58.2	1,109.4	10,854.4
Coefficient, p. ct.	64.91	42.91	66.26	57.05	100.00	44.79	77.75	74.71	63.68	62.66	63.16
Period IV:											
Hay	3,186.4	211.6	2,974.8	408.5	36.3	1,039.7	1,398.8	91.4	73.0	1,453.0	14,177.6
Maize meal.....	3,450.8	50.0	3,400.8	352.0	10.0	75.6	2,817.6	145.6	60.9	1,578.7	15,065.8
Total	6,637.2	261.6	6,375.6	760.5	46.3	1,115.3	4,216.4	237.0	133.0	3,031.7	29,243.4
Feces	1,577.4	154.1	1,423.3	319.3	.....	568.2	497.7	38.2	51.1	760.6	7,330.8
Digested.....	5,059.8	107.5	4,952.3	441.2	46.3	547.1	3,718.7	198.8	81.9	2,271.1	21,912.6
Coefficient, p. ct.	76.23	41.09	77.68	58.01	100.00	49.05	88.20	83.89	61.68	74.92	74.93

TABLE III.—*Digestibility of rations—Continued.*

	Dry mat- ter.	Ash.	Or- ganic mat- ter.	Pro- teids.	Non- pro- teids.	Crude fiber.	Nitro- gen free ex- tract.	Ether ex- tract.	Nitro- gen.	Car- bon.	Ener- gy.
<i>Computed digestibility of maize meal.</i>											
Period III:	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Grms.</i>	<i>Cals.</i>
Total digested...	2,529.9	94.8	2,435.1	276.2	64.1	453.8	1,551.0	89.8	58.2	1,109.4	10,854.4
Computed di- gestible in hay.	1,888.2	97.6	1,789.7	220.5	59.1	500.5	960.47	58.58	47.46	822.3	8,117.0
Digested from maize meal..	641.7	-2.8	645.4	55.7	5.0	-46.7	590.53	31.22	10.74	287.1	2,737.4
Coefficient, p. ct.	87.34	.....	89.16	80.14	100.00	.....	98.11	103.72	85.23	85.42	85.46
Period IV:											
Total digested...	5,069.8	107.5	4,952.3	441.2	46.3	547.1	3,718.7	198.8	81.9	2,271.1	21,912.1
Computed di- gestible in hay.	1,902.3	98.3	1,803.0	207.3	36.3	522.6	964.3	59.4	43.96	832.1	8,230.1
Digested from maize meal..	3,157.5	9.2	3,149.3	233.9	10.0	24.5	2,754.4	139.4	37.94	1,439.0	13,682.0
Coefficient, p. ct.	91.50	18.40	92.60	66.43	100.00	32.40	97.75	95.74	62.30	91.09	90.81

TABLE IV.—*Results on urine (inclusive of wash water).*

Period.	Weight.	Aver- age specific gravity.	Total nitrogen.		Total carbon.		Energy.	
							Pergram.	Total.
Period I:	<i>Grams.</i>		<i>Per ct.</i>	<i>Grams.</i>	<i>Per ct.</i>	<i>Grams.</i>	<i>Calories.</i>	<i>Calories.</i>
Total collected.....	57,537.0	.....	1.303	749.71	2.615	1,504.59	.....	.....
Daily average (10 days)...	5,754.0	1.0413	.....	74.97	.....	150.46	217.2	1,249.8
Period II:								
Total collected.....	48,951.0	.....	1.073	525.24	1.897	928.60	171.2	8,380.4
Spilled in stall Mar. 1.....	85.8	.....	1.513	1.30	^a 2.675	2.30	^a 241.4	20.7
Total.....	49,036.8	1.0403	.....	526.54	.....	930.90	.....	8,401.1
Daily average (9 days).....	5,448.5	.....	.....	58.50	.....	103.43	.....	933.5
Period III:								
Total collected.....	70,086.0	.....	0.843	590.82	1.788	1,253.14	.....	.....
Daily average (10 days)...	7,008.6	1.0365	.....	59.01	.....	125.31	131.4	920.9
Period IV:								
Total collected.....	54,685.0	.....	.....	.....	.....	.....	.....	.....
Spilled in stall Apr. 13.....	^b 50.0	.....	.....	.....	.....	.....	.....	.....
Total.....	54,735.0	.....	1.283	702.25	2.592	1,418.73	.....	11,943.17
Daily average (10 days)...	5,473.5	1.0398	.....	70.23	.....	141.87	218.2	1,194.3

^a Assumed to be proportional to nitrogen content.^b Estimated.

TABLE V.—*Residual air.*

Period.	Aspirator reading.	Barometer. ^a	Temperature.	Weight.		Corresponding volume at 0° and 760 mm.		Total volume of sample reduced.		Volume of moist air in chamber reduced.	Total in chamber.	
				Water.	Carbon dioxide.	Water.	Carbon dioxide.	Dry.	As sample.		Water.	Carbon dioxide.
<i>Period I.</i>	<i>Liters</i>	<i>mm.</i>	<i>°C.</i>	<i>Gms.</i>	<i>Gms.</i>	<i>Liters</i>	<i>Liters</i>	<i>Liters</i>	<i>Liters</i>	<i>Liters</i>	<i>Gms.</i>	<i>Gms.</i>
At end of preliminary run..	25	710.2	19.7	0.1548	0.1066	0.19	0.05	21.84	22.03	10,879	76.45	52.64
At end of subperiod 1.....	25	704.0	16.2	.1432	.1009	.18	.05	21.91	22.09	10,719	69.48	48.96
At end of subperiod 2.....	25	696.2	16.0	.1786	.1196	.22	.06	21.69	21.91	10,626	86.92	58.20
At end of subperiod 3.....	25	701.1	19.8	.1233	.0888	.15	.04	21.54	21.69	10,742	61.00	43.94
At end of subperiod 4.....	25	712.2	18.5	.1599	.1107	.19	.06	22.00	22.19	10,879	78.39	54.27
<i>Period II.</i>												
At end of preliminary run..	25	718.9	18.5	.1395	.0991	.17	.05	22.15	22.32	10,985	68.66	48.77
At end of subperiod 1.....	25	721.3	17.0	.1465	.0971	.18	.05	22.38	22.56	11,014	71.53	47.41
At end of subperiod 2.....	25	725.6	16.6	.1479	.0987	.18	.05	22.55	22.73	11,074	72.06	48.09
At end of subperiod 3.....	25	726.6	15.5	.1225	.0947	.15	.05	22.77	22.92	11,075	59.19	45.76
At end of subperiod 4.....	25	724.1	18.0	.1331	.1107	.17	.06	22.41	22.58	10,845	63.93	53.17
<i>Period III.</i>												
At end of preliminary run..	25	719.1	17.2	.1482	.1044	.18	.05	22.30	22.48	10,985	72.42	51.02
At end of subperiod 1.....	25	720.1	18.3	.1631	.1071	.19	.05	22.25	22.44	11,008	80.01	52.54
At end of subperiod 2.....	25	721.4	17.8	.2030	.1124	.24	.06	22.34	22.58	11,022	99.09	54.87
At end of subperiod 3.....	25	723.7	16.6	.1722	.1121	.21	.06	22.50	22.71	11,045	83.75	54.52
At end of subperiod 4.....	25	719.8	17.4	.2006	.1185	.24	.06	22.32	22.56	10,998	97.79	57.77
<i>Period IV.</i>												
At end of preliminary run..	25	708.1	20.0	.2008	.1514	.24	.08	21.78	22.02	10,862	99.05	74.68
At end of subperiod 1.....	25	710.4	18.8	.2167	.1405	.26	.07	21.93	22.19	10,635	103.86	67.34
At end of subperiod 2.....	25	709.0	18.2	.2004	.1487	.25	.07	21.93	22.18	10,847	98.01	72.72
At end of subperiod 3.....	25	711.8	19.3	.2035	.1382	.25	.07	21.94	22.19	10,906	100.02	67.92
At end of subperiod 4.....	25	710.7	17.6	.2069	.1525	.26	.08	22.04	22.30	10,864	100.80	74.29

^a Corrected for tension of aqueous vapor. The air in the aspirator is assumed to be saturated.

TABLE VI.—*Ventilation.*

Period.	Volume at meter pump.	Average barome- ter.	Average tension of aque- ous vapor.	Average tempera- ture.	Reduced volume at meter pump, dry.	Sample of resid- ual air.	Methane pro- duced.	Volume of entering air, dry.
<i>Period I.</i>	<i>Liters.</i>	<i>mm.</i>	<i>mm.</i>	<i>°C.</i>	<i>Liters.</i>	<i>Liters.</i>	<i>Liters.</i>	<i>Liters.</i>
Subperiod 1.....	490,773	720.9	1.54	16.7	437,738.8	21.9	73.9	437,686.9
Subperiod 2.....	477,546	711.7	2.53	17.1	419,407.2	21.7	73.6	419,355.3
Subperiod 3.....	495,281	714.8	2.70	17.1	436,729.2	21.5	72.8	436,677.9
Subperiod 4.....	486,562	722.5	2.16	17.6	433,252.9	22.0	69.2	433,205.7
<i>Period II.</i>								
Subperiod 1.....	473,732	735.2	1.47	18.4	428,453.7	22.4	58.2	428,422.9
Subperiod 2.....	460,159	739.0	1.13	16.2	421,732.8	22.6	51.1	421,704.3
Subperiod 3.....	460,208	739.7	1.20	15.9	422,577.3	22.8	54.9	422,545.2
Subperiod 4.....	455,007	740.1	0.98	16.6	417,079.1	22.4	55.3	417,046.2
<i>Period III.</i>								
Subperiod 1.....	462,090	734.8	2.17	16.1	420,691.8	22.3	72.2	420,641.9
Subperiod 2.....	455,056	737.0	1.91	17.1	414,154.4	22.3	71.4	414,105.3
Subperiod 3.....	467,242	737.4	1.80	16.3	426,728.2	22.5	75.1	426,675.6
Subperiod 4.....	460,307	736.8	1.56	15.7	421,065.4	22.3	72.5	421,015.2
<i>Period IV.</i>								
Subperiod 1.....	461,100	726.6	2.64	17.8	412,274.4	21.9	120.6	412,175.7
Subperiod 2.....	455,700	724.3	1.57	17.0	407,931.7	21.9	133.8	407,819.8
Subperiod 3.....	474,822	727.2	2.23	17.5	425,639.2	21.9	126.5	425,534.6
Subperiod 4.....	463,676	727.5	2.35	17.4	415,885.4	22.0	132.6	415,774.8

TABLE VII.—*Ingoing air.*

Period.	Aspi- rator read- ing.	Ba- rome- ter. a	Tem- pera- ture.	Re- duced aspira- tor read- ing, dry.	Volum- e of car- bon diox- ide.	Total volume of sam- ple re- duced and dry.	Ratio of sam- ple to total ventila- tion.	Water.		Carbon diox- ide.	
								In sam- ple.	In total ventila- tion.	In sam- ple.	In to- tal ven- tila- tion.
<i>Period I.</i>	<i>Liters</i>	<i>mm.</i>	<i>°C.</i>	<i>Liters.</i>	<i>Liters</i>	<i>Liters.</i>	<i>1 :</i>	<i>Gram.</i>	<i>Grams.</i>	<i>Gram.</i>	<i>Gms.</i>
Subperiod 1	200	700.8	17.8	173.12	0.06	173.18	2,527.4	0.4039	1,020.8	0.1124	284.01
Subperiod 2	200	695.9	18.4	171.58	.06	171.64	2,443.2	.4209	1,028.4	.1102	269.2
Subperiod 3	200	702.3	21.8	172.04	.05	172.09	2,537.5	.4318	1,095.7	.1046	265.4
Subperiod 4	200	712.0	19.6	174.82	.05	174.87	2,477.3	.2896	717.4	.1013	251.0
<i>Period II.</i>											
Subperiod 1	43.5	719.3	19.4	38.44	.01	38.45	11,142.3	.0682	759.9	.0251	279.7
Subperiod 2	200	724.1	18.4	178.52	.05	178.57	2,361.6	.3597	849.5	.1094	258.4
Subperiod 3	200	726.0	19.4	178.37	.06	178.43	2,368.1	.2204	521.9	.1128	267.1
Subperiod 4	200	724.5	20.6	177.28	.06	177.34	2,351.7	.2100	493.9	.1165	274.0
<i>Period III.</i>											
Subperiod 1	200	720.2	20.0	176.58	.06	176.64	2,381.4	.5241	1,248.1	.1188	282.9
Subperiod 2	200	721.2	19.6	177.09	.06	177.15	2,337.6	.4369	1,021.3	.1202	281.0
Subperiod 3	200	723.7	18.0	178.66	.06	178.72	2,387.4	.8396	2,004.5	.1168	278.9
Subperiod 4	200	720.4	19.8	176.75	.06	176.81	2,381.2	.1655	394.1	.1150	273.8
<i>Period IV.</i>											
Subperiod 1	200	711.0	20.4	174.09	.06	174.15	2,366.8	.7725	1,828.4	.1137	269.1
Subperiod 2	200	708.6	19.8	173.85	.06	173.91	2,345.0	.1264	296.4	.1110	260.3
Subperiod 3	200	713.1	21.0	174.25	.06	174.31	2,441.3	.0924	225.6	.1117	272.7
Subperiod 4	200	711.4	19.0	175.03	.05	175.08	2,374.8	.0772	183.3	.1066	253.2

^a Corrected for tension of aqueous vapor. The air in the aspirator is assumed to be saturated.

TABLE VIII.—Carbon dioxide.

Period.	Carbon dioxide in samples (corrected). ^a		Total, Nos. 1 and 2 × 100 and cor- rected. ^b	In sam- ple of resid- ual air.	Correc- tion for residual air.	Total CO ₂ in out- coming air.	Total CO ₂ in ingoin air.	CO ₂ added in cham- ber.	Equiv- alent carbon.
	Pan No. 1.	Pan No. 2.							
<i>Period I.</i>									
	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Gram.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Subperiod 1.....	12. 3144	12. 1553	2, 454. 3	0. 10	— 3. 7	2, 450. 7	284. 1	2, 166. 6	590. 8
Subperiod 2.....	12. 1142	12. 1389	2, 432. 8	. 1	+ 9. 2	2, 442. 1	269. 2	2, 172. 9	592. 6
Subperiod 3.....	12. 4777	12. 3708	2, 492. 3	. 1	— 14. 3	2, 478. 1	265. 4	2, 212. 7	603. 4
Subperiod 4.....	11. 9475	11. 8761	2, 389. 5	. 1	+ 10. 3	2, 399. 9	251. 0	2, 148. 9	586. 0
<i>Period II.</i>									
Subperiod 1.....	10. 5350	Lost.	2, 113. 3	. 1	— 1. 4	2, 112. 0	279. 7	1, 832. 3	499. 7
Subperiod 2.....	10. 6092	10. 5461	2, 121. 8	. 1	+ 0. 7	2, 122. 6	258. 4	1, 864. 2	508. 4
Subperiod 3.....	10. 6495	10. 5518	2, 126. 4	. 1	— 2. 3	2, 124. 2	267. 1	1, 857. 1	506. 4
Subperiod 4.....	10. 3482	10. 3452	2, 075. 5	. 1	+ 7. 4	2, 083. 0	274. 9	1, 809. 0	493. 3
<i>Period III.</i>									
Subperiod 1.....	11. 2609	11. 2802	2, 260. 8	. 1	+ 1. 5	2, 262. 4	282. 9	1, 979. 5	539. 8
Subperiod 2.....	11. 3133	11. 3365	2, 271. 7	. 1	+ 2. 3	2, 274. 1	281. 0	1, 993. 1	543. 5
Subperiod 3.....	11. 9475	11. 9567	2, 397. 6	. 1	— 0. 4	2, 397. 3	278. 9	2, 118. 4	577. 7
Subperiod 4.....	11. 3273	11. 3569	2, 275. 1	. 1	+ 3. 3	2, 278. 5	273. 8	2, 004. 7	546. 7
<i>Period IV.</i>									
Subperiod 1.....	16. 4772	16. 6405	3, 321. 6	. 1	— 7. 3	3, 314. 4	269. 1	3, 045. 3	830. 5
Subperiod 2.....	16. 7846	16. 9196	3, 380. 4	. 2	+ 5. 4	3, 386. 0	260. 3	3, 125. 7	852. 4
Subperiod 3.....	16. 3318	16. 4606	3, 289. 0	. 1	— 4. 8	3, 284. 3	272. 7	3, 011. 6	821. 3
Subperiod 4.....	16. 4890	16. 8123	3, 340. 1	. 2	+ 6. 4	3, 346. 6	253. 2	3, 093. 4	843. 6

^a For number of pump strokes.^b For a slight leakage from the pans, amounting to about 0.3 per cent of the total volume.

TABLE IX.—*Water.*

Period.	Water in samples (corrected), ^a		Total, Nos. 1 and 2×100 (corrected), ^b	In cans.	On absorbers.	In sample of residual air.	Correction for residual air.	Correction of hygrometer.	Total H ₂ O in outgoing air + absorbers	Total H ₂ O in ingoing air.	Water added in chamber.	Equivalent hydrogen.
	Pan No. 1.	Pan No. 2.										
Period I.												
Subperiod 1.....	Gms. 7.6365	Gms. 7.6004	Gms. 1,538.21, 368.0		Gms. 0.0	Gm. 0.1	Gms. — 6.9	Gms. — 3.03, 386.4	Gms. 1,020.8, 2, 365.6	Gms. 262.9		
Subperiod 2.....	6.1590	6.1232	1,232.0, 2, 138.0		10.0	.2	+17.4	— 3.03, 394.6	1,028.4, 2, 366.2	262.9		
Subperiod 3.....	5.7351	5.6921	1,146.1, 2, 185.0		— 10.0	.1	—25.9	— 3.03, 292.3	1,095.7, 2, 196.9	244.0		
Subperiod 4.....	5.3240	5.2879	1,064.41, 906.0		17.0	.2	+17.4	— 3.03, 002.0	717.4, 2, 284.5	238.5		
Period II.												
Subperiod 1.....	3.5192	Lost.	705.9, 2, 024.0		.0	.1	+ 2.9	— 3.02, 729.9	759.9, 1, 970.0	218.9		
Subperiod 2.....	2.6218	2.6181	525.6, 2, 610.0		.0	.1	+ 0.5	— 3.03, 133.2	849.5, 2, 283.7	253.8		
Subperiod 3.....	2.8104	2.8134	564.1, 2, 235.0		.0	.1	—12.9	— 3.02, 783.3	521.9, 2, 261.4	251.3		
Subperiod 4.....	2.2498	2.2443	450.8, 2, 340.0		.0	.1	+ 4.7	— 3.02, 792.6	489.9, 2, 298.7	255.4		
Period III.												
Subperiod 1.....	5.0911	5.0179	1,013.9, 2, 435.0		34.0	.2	+ 7.6	— 3.03, 487.7	1,248.1, 2, 239.6	248.9		
Subperiod 2.....	4.3881	4.4001	882.4, 2, 563.0		101.0	.2	+19.1	— 3.03, 562.7	1,021.3, 2, 541.4	282.4		
Subperiod 3.....	4.2473	4.2538	852.9, 3, 290.0		288.0	.2	—15.3	— 3.04, 412.8	2,004.5, 2, 408.3	267.6		
Subperiod 4.....	3.6406	3.6510	731.3, 2, 389.0		—270.8	.2	+14.0	— 3.02, 840.7	894.1, 2, 446.6	271.9		
Period IV.												
Subperiod 1.....	6.1830	6.1550	1,238.5, 3, 092.0		1, 235.0	.2	+ 4.8	— 3.05, 567.5	1,828.4, 3, 739.1	415.5		
Subperiod 2.....	4.6118	4.6369	927.6, 3, 168.0		237.0	.2	— 5.9	— 3.04, 323.9	296.4, 4, 027.5	447.5		
Subperiod 3.....	5.3601	5.3707	1,076.3, 3, 150.0		— 17.0	.2	+ 2.0	— 3.04, 208.5	225.6, 3, 382.9	442.6		
Subperiod 4.....	5.5070	5.5432	1,108.3, 2, 907.0		321.6	.2	+ 0.8	— 3.04, 334.9	183.3, 4, 151.6	461.3		

^a For number of pump strokes.^b For slight leakage from pans, see previous table.

TABLE X.—Carbon and hydrogen in combustible gases.

Period. ^a	Total CO ₂ weighed ×200.	Correc- tion for ingoing air.	Carbon as hydro- carbon (cor- rected). ^a	Total H ₂ O weighed ×200.	Correc- tion for ingoing air.	Hydro- gen as hydro- carbons (cor- rected). ^a	Methane, CO ₂ × .3643.
<i>Period I.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Subperiod 1.....	146.58	-2.70	39.38	121.74	-9.53	12.52	52.62
Subperiod 2.....	145.96	-2.58	39.25	119.88	-9.13	12.36	52.44
Subperiod 3.....	144.68	-2.69	38.84	120.78	-9.51	12.40	51.89
Subperiod 4.....	137.58	-2.67	36.90	113.88	-9.44	11.64	49.80
<i>Period II.</i>							
Subperiod 1.....	106.24	-2.64	28.34	87.04	-9.33	8.66	37.86
Subperiod 2.....	102.12	-2.60	27.22	85.14	-9.18	8.47	36.37
Subperiod 3.....	109.60	-2.60	29.29	87.12	-9.20	8.69	39.13
Subperiod 4.....	110.40	-2.57	29.50	88.26	-9.08	8.83	39.41
<i>Period III.</i>							
Subperiod 1.....	143.16	-2.59	38.47	121.32	-9.16	12.51	51.40
Subperiod 2.....	141.80	-2.55	38.09	118.10	-9.02	12.16	50.89
Subperiod 3.....	149.08	-2.63	40.06	123.42	-9.29	12.72	53.52
Subperiod 4.....	143.84	-2.60	38.66	118.82	-9.17	12.23	51.65
<i>Period IV.</i>							
Subperiod 1.....	236.82	-2.54	64.32	196.56	-8.98	20.92	85.93
Subperiod 2.....	263.40	-2.51	71.36	216.64	-8.88	23.16	95.34
Subperiod 3.....	249.16	-2.62	67.43	204.84	-9.27	21.80	90.08
Subperiod 4.....	260.90	-2.56	70.70	215.30	-9.06	23.00	94.46

^a For slight leakage from pans, see previous table.

TABLE XI.—*Heat measurements—Continued.*

Period.	Relative rate of flow.	Average temperature of water current.					Total water.	Average specific heat of water.	Heat produced in absorbers.		Total heat, Calories at 20°.
		Ingoing.	Outgoing.	Difference.	Correction for pressure.	Corrected difference.			Difference of pressure.	Equivalent heat.	
PERIOD II—Cont'd.											
Subperiod 3.		°C.	°C.	°C.	°C.	°C.	Liters.		Cm.	Cal.	
6.00 p. m. to 7.36 p. m..	28.0	5.3020	12.2480	6.9460	0.0006	6.9466	73.25	1.0037	0.30	0.91	510.71
7.36 p. m. to 9.00 p. m..	30.0	4.7448	8.6362	3.8914	.0010	3.8924	133.25	1.0047	.50	.02	521.08
9.00 p. m. to 9.47 p. m..	28.0	5.2845	10.6518	5.3673	.0006	5.3679	35.50	1.0040	.30	.....	191.32
9.47 p. m. to 11.58 p. m.	27.5	5.6967	12.0906	6.3939	.0005	6.3944	76.75	1.0036	.25	.01	492.53
11.58 p. m. to 1.54 a. m..	29.5	4.6900	9.2679	4.5779	.0009	4.5788	162.75	1.0046	.45	.03	748.60
1.54 a. m. to 3.50 a. m..	27.5	5.6234	12.2586	6.6352	.0005	6.6357	72.50	1.0036	.25	.01	482.81
3.50 a. m. to 4.48 a. m..	29.5	4.2513	9.8733	5.6220	.0009	5.6229	73.00	1.0045	.45	.01	412.31
4.48 a. m. to 6.00 a. m..	27.5	5.1135	11.5924	6.4789	.0005	6.4794	42.25	1.0039	.25	.....	274.82
Latent heat of water vapor.....											3,634.18
Correction for feed, water, excreta, and vessel.....											1,338.75
Total heat.....											-1.61
Subperiod 4.											4,971.32
6.00 a. m. to 8.48 a. m..	27.5	5.1153	12.3023	7.1870	.0005	7.1875	100.00	1.0037	.25	.01	721.40
8.48 a. m. to 9.06 a. m..	27.5	5.1700	13.3700	8.2000	.0005	8.2005	10.00	1.0035	.25	.....	82.29
9.06 a. m. to 11.12 a. m..	29.0	4.4678	10.3893	5.9216	.0008	5.9224	134.00	1.0043	.40	.02	796.99
11.12 a. m. to 3.16 p. m..	27.5	5.7682	11.9164	6.1482	.0005	6.1487	158.57	1.0036	.25	.01	978.50
3.16 p. m. to 3.20 p. m..	27.5	6.3400	13.1200	6.7800	.0005	6.7805	3.43	1.0032	.25	.....	23.33
3.20 p. m. to 6.00 p. m..	29.0	5.7623	10.8715	5.1092	.0008	5.1100	185.625	1.0038	.40	.02	952.13
Latent heat of water vapor.....											3,554.64
Correction for feed, water, excreta, and vessel.....											1,360.83
Total heat.....											+28.69
PERIOD III.											4,944.16
Subperiod 1.											
6.00 p. m. to 6.06 p. m..	42.0	7.2900	8.3500	1.0600	.0122	1.0722	32.00	1.0040	7.00	.07	34.38
6.06 p. m. to 7.45 p. m..	40.0	7.2088	8.3396	1.1308	.0098	1.1406	501.00	1.0041	5.60	.89	572.89
7.45 p. m. to 8.04 p. m..	35.0	7.1880	8.6740	1.4860	.0040	1.4900	67.00	1.0040	2.50	.06	100.18
8.04 p. m. to 8.17 p. m..	34.0	7.2367	8.8500	1.6133	.0032	1.6165	41.00	1.0039	2.00	.03	66.50
8.17 p. m. to 8.33 p. m..	33.0	7.2950	9.0900	1.7950	.0028	1.7978	41.00	1.0039	1.50	.02	73.98
8.33 p. m. to 11.15 p. m.	31.0	7.5588	9.8495	2.2907	.0012	2.2919	307.00	1.0036	.75	.17	705.98
11.15 p. m. to 1.04 a. m..	39.0	8.0296	9.5564	1.5268	.0086	1.5354	522.00	1.0035	4.75	.79	803.49
1.04 a. m. to 2.12 a. m..	31.0	7.2876	9.7776	2.4900	.0012	2.4912	123.00	1.0037	.75	.07	307.48
2.12 a. m. to 3.19 a. m..	20.0	7.4362	10.2675	2.8313	.0010	2.8323	105.03	1.0035	.50	.02	298.41
3.19 a. m. to 6.00 a. m..	39.0	6.9560	8.3215	1.3655	.0086	1.3741	760.50	1.0041	4.75	1.15	1,048.14
Latent heat of water vapor.....											4,011.43
Correction for feed, water, excreta, and vessel.....											1,305.77
Total heat.....											+1.63
											5,318.83

TABLE XI.—Heat measurements—Continued.

Period.	Relative rate of flow.	Average temperature of water current.					Total water.	Average specific heat of water.	Heat produced in absorbers.		Total heat, Calories at 20°.
		Ingoing.	Outgoing.	Difference.	Correction for pressure.	Corrected difference.			Difference of pressure.	Equivalent heat.	
PERIOD III—Cont'd.											
Subperiod 2.											
		°C.	°C.	°C.	°C.	°C.	Liters.		Cm.	Cal.	
6.00 a. m. to 7.30 a. m..	39.0	6.7987	8.0569	1.2582	0.0086	1.2668	423.00	1.0042	4.75	0.64	537.47
7.30 a. m. to 7.50 a. m..	38.0	6.7900	8.0160	1.2260	.0074	1.2334	89.17	1.0042	4.00	.11	110.33
7.50 a. m. to 7.56 a. m..	38.0	6.8100	7.8200	1.0100	.0074	1.0174	24.33	1.0043	4.00	.03	24.83
7.56 a. m. to 8.29 a. m..	31.0	7.0813	9.0450	1.9637	.0012	1.9649	63.50	1.0039	.75	.02	125.24
8.29 a. m. to 8.45 a. m..	29.0	7.4725	10.8075	3.3350	.0008	3.3358	18.00	1.0034	.40	.....	60.25
8.45 a. m. to 11.47 a. m..	28.0	8.1118	12.8844	4.7726	.0006	4.7732	121.00	1.0028	.30	.01	579.16
11.47 a. m. to 12.44 p. m.	36.0	7.9040	9.7840	1.8800	.0050	1.8850	213.00	1.0035	3.00	.20	402.71
12.44 p. m. to 3.44 p. m..	29.0	8.2912	11.7806	3.4894	.0008	3.4902	225.00	1.0030	.40	.03	787.62
3.44 p. m. to 4.32 p. m..	36.0	8.6617	10.4258	1.7641	.0050	1.7691	169.00	1.0032	3.00	.16	299.77
4.32 p. m. to 6.00 p. m..	38.0	9.5914	8.1668	1.4246	.0074	1.4320	389.00	1.0035	4.00	.49	558.51
Latent heat of water vapor.....											3,485.89
Correction for feed, water, excreta, and vessel.....											1,444.79
Total heat.....											+40.85
Subperiod 3.											
6.00 p. m. to 6.52 p. m..	38	7.8007	9.2421	1.4414	.0074	1.4488	230.50	1.0037	4.00	.29	334.89
6.52 p. m. to 7.34 p. m..	29	8.2110	11.6580	3.4470	.0008	3.4478	52.00	1.0030	.40	.01	179.81
7.34 p. m. to 9.23 p. m..	38	7.6689	9.2863	1.6174	.0074	1.6248	491.50	1.0037	4.00	.62	800.92
9.23 p. m. to 9.31 p. m..	29	7.6350	10.0250	2.3900	.0008	2.3908	8.00	1.0035	.40	.....	19.19
9.31 p. m. to 11.11 p. m.	38	7.3864	8.9948	1.6084	.0074	1.6158	446.00	1.0038	4.00	.57	722.82
11.11 p. m. to 12.11 a. m.	29	7.7366	11.1186	3.3820	.0008	3.3828	72.00	1.0033	.40	.01	244.36
12.11 a. m. to 2.33 a. m..	28	7.2953	8.8967	1.6014	.0006	1.6020	620.00	1.0039	.30	.06	997.05
2.33 a. m. to 3.18 a. m..	29	7.6055	11.0782	3.4727	.0008	3.4735	51.50	1.0033	.40	.01	179.47
3.18 a. m. to 6.00 a. m..	38	7.1295	8.5090	1.3795	.0074	1.3869	710.00	1.0041	4.00	.09	988.65
Latent heat of water vapor.....											4,467.16
Correction for feed, water, excreta, and vessel.....											1,255.33
Total heat.....											-5.98
Subperiod 4.											
6.00 a. m. to 6.49 a. m..	38	7.0377	8.4338	1.3961	.0074	1.4035	200.00	1.0041	4.00	.25	281.60
6.49 a. m. to 7.09 a. m..	35	7.0520	8.6540	1.6020	.0040	1.6060	71.00	1.0040	2.50	.06	114.42
7.09 a. m. to 7.26 a. m..	33	7.0750	8.9475	1.8725	.0024	1.8749	43.00	1.0040	1.50	.02	80.92
7.26 a. m. to 8.40 a. m..	30	7.3128	10.1811	2.8683	.0010	2.8693	117.00	1.0036	.50	.02	336.90
8.40 a. m. to 11.17 a. m.	28	8.0618	11.9570	3.8952	.0006	3.8958	141.00	1.0030	.30	.01	550.95
11.17 a. m. to 11.26 a. m.	30	8.1450	11.3650	2.9900	.0010	2.9910	15.00	1.0032	.50	.....	45.01
11.26 a. m. to 12.03 p. m.	34	8.0456	10.0767	2.0311	.0032	2.0343	113.00	1.0034	2.00	.07	230.59
12.03 p. m. to 2.14 p. m.	37	7.9770	9.4718	1.4948	.0062	1.5010	520.00	1.0036	3.50	.58	782.75
2.14 p. m. to 4.18 p. m..	28	8.6094	12.9810	4.3716	.0006	4.3722	106.00	1.0026	.30	.01	464.65
4.18 p. m. to 5.18 p. m..	31	8.8580	11.2100	2.3520	.0012	2.3532	113.00	1.0029	.75	.06	266.62
5.18 p. m. to 5.33 p. m..	37	8.9600	10.4350	1.4750	.0062	1.4812	61.00	1.0032	3.50	.07	90.57

TABLE XI.—*Heat measurements*—Continued.

Period.	Relative rate of flow.	Average temperature of water current.				Total water.	Average specific heat of water.	Difference of pressure.	Heat produced in absorbers.	Equivalent heat.	Total heat, Calories at 20°.
		Ingoing.	Outgoing.	Difference.	Correction for pressure.	Corrected difference.					
PERIOD IV—Cont'd. <i>Subperiod 3</i> —Cont'd.											
Latent heat of water vapor.....		°C.	°C.	°C.	°C.	°C.	Liters.	Cm.	Cal.	2,367.96	
Correction for heat, water, excreta, and vessel.....											-4.55
Total heat.....											7,085.07
<i>Subperiod 4.</i>											
6.00 a. m. to 6.04 a. m..	29	7.8200	11.6200	3.7900	0.0008	3.7908	6.00	1.0031	0.40	.....	22.82
6.04 a. m. to 11.24 a. m..	47	6.6855	8.7685	2.0830	.0136	2.1026	1,194.00	1.0041	10.25	3.88	2,516.92
11.24 a. m. to 2.24 p. m..	29	6.0264	10.4752	4.4488	.0008	4.4496	200.00	1.0039	.40	.04	893.35
2.24 p. m. to 6.00 p. m..	47	6.6894	8.8813	2.1919	.0136	2.2115	754.50	1.0041	10.25	2.45	1,672.97
Latent heat of water vapor.....											5,106.06
Correction for feed, water, excreta, and vessel.....											2,267.85
Total heat.....											+45.56
											7,418.97